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Development, Location, and the Workplace
Part 2: Working Papers, Part C
Individual Education and Training Case Studies

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COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

This is an OTA Working Paper that has neither been reviewed nor
approved by the Technology Assessment Board

July 1984



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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

VOLUME II - WORKING PAPERS

Part C - Individual Education and Training Case Studies

- C.1--CINCINNATI MILACRON INDUSTRIES, INC.
- C.2--GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI: "NEW TECHNOLOGY TRAINING"
- C.3--BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS
- C.4--CAD/CAM OPERATOR TRAINING PROGRAM, GLENDALE, CALIFORNIA
- C.5--MANUFACTURING ENGINEERING APPLICATIONS CENTER, WORCESTER, MA
- C.6--NEW ENGLAND PROGRAMMABLE AUTOMATION CUSTOMER TRAINING: COMPUTERVISION, GCA, AUTOMATIX
- C.7--OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS: ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS
- C.8--UNIVERSITY OF MICHIGAN
- C.9--CADAM, INC.: CUSTOMER TRAINING IN COMPUTER-AIDED DESIGN
- C.10--HENRY FORD COMMUNITY COLLEGE: ELECTRICAL-ELECTRONIC TECHNOLOGY PROGRAM, AUTOMATION/ROBOTICS OPTION
- C.11--WESTINGHOUSE DEFENSE AND ELECTRONICS SYSTEMS CENTER, BALTIMORE, MD
- C.12--TEXAS INSTRUMENTS
- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

C.1— Cincinnati Milacron Industries, Inc.

This is an OTA Working Paper that has neither been reviewed nor
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July 1984



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Office of Technology Assessment
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:
CINCINNATI MILACRON INDUSTRIES, INC.

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
*** 1984

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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

CINCINNATI MILACRON INDUSTRIES, INC.

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CINCINNATI MILACRON INDUSTRIES, INC.

EMPLOYEE AND CUSTOMER TRAINING:

CNC MACHINE TOOLS, ROBOTICS, PROGRAMMABLE CONTROL SYSTEMS

I. BACKGROUND/SUMMARY

Cincinnati Milacron Industries, Inc. (CMI), headquartered in Cincinnati, Ohio, is the largest machine-tool maker in the United States (1982 sales: \$759 million) and is one of the country's two largest robot manufacturers. With 19 plants in the United States and 11 overseas manufacturing facilities, the firm designs, manufactures, and sells process equipment for industry along with supplies and accessories used in such systems.

The largest of CMI's manufacturing divisions is the Machine Tool Group, which produces an extensive line of numerical-control (CNC) machine tools, including machining centers, turning centers, milling machines, and grinding machines. Together with the machine-tool-related control systems designed and produced by the firm's Electronic Systems Division, machine tools accounted for 66.5 percent of the total 1981 sales (\$639.5 million). The Plastics Machinery Division--which manufactures injection molding machines, extruders, reheat blow molding machines--and other divisions which manufacture robots, semiconductor materials, cutting fluid, grinding wheels, and printed circuit board materials made up 16.9 percent of total sales in 1981.

CMI also designs and produces manufacturing systems that combine processing machinery, tooling, and material handling equipment. The "Variable Mission Manufacturing System"--a modular, computer-automated, flexible manufacturing system capable of producing different parts and adapting automatically to different mixes of part types--was introduced in 1968.

At the present time, CMI offers customer training on its computer-aided manufacturing equipment through four sales and service divisions: 1) machine tools, 2) electronic systems, 3) industrial robots, and 4) plastics machinery. The training departments in these four divisions provide instruction to CMI customers and supplement in-plant employee training.

delivered by Milacron's corporate training department with machine-specific training courses and courses covering the fundamentals of computers, electronics, logic devices, machining, and grinding.

Section II of this study describes the skills training offered by the Machine Tool, Electronic Systems, and Industrial Robot Divisions. The Plastics Machinery Division, which delivers less computer-aided-manufacturing (CAM) training than the others, is not a subject for further reporting in the current study. The three training groups covered instruct a wide variety of customer and CMI personnel, including machine operators, programmers, process engineers, electricians, machine repair persons, welders, group supervisors, and CMI sales vice representatives.

While most of the customer training is delivered at CMI training facilities and focuses on skills and information required to operate and maintain specific machine tool, robot, or controls systems, the Cincinnati trainers also have the capacity to aid customers who wish to implement training programs in their own plants.

Organizational View of Training and Education

Cincinnati Milacron's historical commitment to skills training is traced by today's employees back to F. A. Geier, the founder of the company and grandfather of the firm's current chairman of the board and chief executive officer. Although the company has never been unionized, it has a 98-year-old apprenticeship program, which at one time was almost identical to skills training approved by the Federal Bureau of Apprenticeship and Training (BAT).*

Aside from creating the in-house apprenticeship program, F. A. Geier joined with six other company presidents and the University of Cincinnati to form one of the first cooperative education programs in 1906. The program, which has grown to include co-op students from over 35 colleges and universities, is

* CMI's apprenticeship training programs began to depart from those approved by BAT in the early sixties. At that time, the company adopted a policy that determined the amount of time allotted to training by the individual trainee's "level of attainment" (i.e., previously acquired skills) rather than adhering to the fixed number of hours for classroom and on-the-job training required by BAT for all apprenticeship programs.

still in existence and CMI draws many of its managerial, professional, and technical staff from employees trained through the co-op system.

From 1935 until the late sixties, CMI had a senior training committee, made up of all the company's divisions, chaired by a senior executive who, in addition to his regular assignment, was also chief executive training officer. The training committee was disbanded in the late 1960's when the position of Vice President of Personnel and Community Relations was created. This title was changed subsequently to Vice President of Human Resources. However, the corporate training manager reports that the tradition of cooperation between those responsible for training and those responsible for production still exists and that production managers understand the need for their backing if training is to be effective. Furthermore, since many of the division heads are co-op graduates who themselves completed thousands of hours of training, skills training has the support of top management; and training requirements are coordinated with production requirements in long-term development planning and daily divisional and departmental activities.

Traditional Skills Training

Between 1975 and 1980, CMI employees spent 1.5 million hours in training sessions, both in-plant and at colleges and universities. Aside from training for co-op students and apprentices, the corporate personnel development department holds sessions for foremen and supervisors; conducts finance, planning, marketing, and other courses for managerial and marketing staff; operates a vestibule school for entry-level shop-floor workers; coordinates new-plant start-up training; organizes specialized training at the request of division managers; coordinates performance appraisal systems; internal search for job openings; administers the corporate tuition aid program; and offers evening courses (no tuition charge) to employees in an evening program conducted in company classrooms. Management Succession Planning, Management Development, and Employee Communications are also functions of the department.

The economic situation in the past few years, however, has forced the company to lay off some of its employees, make reductions in hiring, and reduce the number of apprentices (CMI had one apprentice in 1982, as compared to 17 in 1977) and co-op students (121 students from over 30 colleges and universities

are still on the payroll as compared to 160 in 1979). Changing social patterns have also affected traditional skills training at CMI. Whereas apprentices (usually college-calibre students fresh out of high school) once received 14,000 hours of training covering all aspects of production and management, over the years this requirement was gradually reduced first to 10,000, then 8,000, then 6,000, and now stands at 3,000 hours.

According to the corporate manager of training and development, the recession itself is a major cause of the reduced number of apprentices; when and if the recession comes to an end, CMI will work to strengthen the 3,000 hour apprenticeship program and will probably seek official approval from the EAT. Another reason is that there are many more diverse and specialized jobs today.

Computer-Aided Manufacturing Skills Training

While the figures in the preceding section may indicate either a permanent or temporary decline in some traditional skills-training areas, training in the skills required to program, operate, and maintain CAM equipment has burgeoned and has added a new dimension to Cincinnati Milacron's training activities. As CMI began producing CAM equipment, it recognized the need to provide its customers, as well as its employees, with the skills and knowledge necessary to work on and maintain CAM equipment. Since the late 1960's, four customer training and service departments have been created, the largest of which, the Machine Tool Division Training Department, delivered approximately 3,000 weeks of training in 1982, most of it in CNC machine skills. The other divisions offering training to customers are the Electronic Systems Division (which offers training on programmable controllers and other electronic machine controls), the Plastics Machinery Group (which delivers some CAM training on sensing devices used with the equipment), and the Industrial Robot Division. Customer training is now being delivered in the company's regional technical centers. Training in these technical centers is expected to increase significantly due to lower costs.

Although the major goal of customer training departments is to serve the customers and the division service representatives (who install, demonstrate, and repair the complex equipment), they also provide specialized machine-

specific training to other CMI employees. One department, the Machine Tool Training Group, also delivers basic courses in machining fundamentals, computer fundamentals, and other skill areas which are prerequisites for the CAM courses.

While the customer and service representative training departments are responsible to separate production and sales divisions, and, therefore, maintain a large degree of individual independence, the Corporate Personnel Development Department has oversight and quality control responsibility. Furthermore, there is a great deal of formal and informal cooperation and coordination between the individual customer-training departments. For example, the training on the machine controls offered free to customers who purchase machine tool systems was developed by and is delivered by the Electronic Systems Division (ESD) trainers, while ESD frequently sends its service representatives to the basic skills courses given by the Machine Tools Division.

Relationships with Educational Institutions

Apart from its long experience with cooperative education, Cincinnati Milacron has pursued a policy of active collaboration with educational institutions. The company's activities in this area take a variety of forms, including donations of money and equipment, aid to local high schools, and participation in technical school, college and university training and education programs. The following examples are a small sample of those activities:

- o The Industrial Robots Division has given advice to many of the growing numbers of colleges and universities that are developing robotics curricula.
- o The Machine Tool Division offers free training to college or university instructors who teach courses involving CNC machine skills or technology.
- o The Electronic Systems Division provided programmable controller training free of charge to instructors from Cincinnati Technical

College to prepare them to teach a course in those controls at the college.

- o In 1980, the Corporate Training Department's vestibule school trainers worked with instructors from two of South Carolina's State technical colleges to provide entry-level training to prepare South Carolina residents to apply for operator and assembler positions at two new Cincinnati Milacron plants in Fountain Inn and Greenwood, S.C. The State had the responsibility for interviewing, testing, and selecting the trainees. Training for both plants (ranging from 36 hours to 160 hours of orientation and basic skills training and 80 to 480 hours of in-plant training on specific equipment) was conducted by CMI trainers and State college instructors, some of whom were brought to Cincinnati to take the Machine Tool Division's customer courses to prepare themselves to train the potential employees for the South Carolina facility. A total of 195 State residents entered the training programs and 153 completed it. Over 14 percent were women and 17 percent were members of other minority groups. Almost all of those who graduated and who applied for jobs were hired by Cincinnati Milacron.

Training Facilities and Equipment

Training facilities and equipment are maintained by Corporate Personnel Development in Cincinnati. Corporate training facilities include a training shop, classrooms, and an audio-visual and television studio. In addition, each customer training department has separate facilities.

The majority of the machine tool training is delivered at the Oakley Complex in Cincinnati, which also houses corporate headquarters and some of CMI's research, development, and production facilities. The Machine Tool Training group makes use of the Corporate training facilities, plus a laboratory and two demonstration areas, totaling 5,500 square feet, in the same plant adjacent to the production area.

The robotics training facility consists of classrooms surrounding a laboratory adjacent to customer demonstration areas and close to application engineering

areas. Thus, not only can trainees work on the equipment "dedicated" to training purposes, but they can also view the robots being tested and demonstrated.

The Electronic Systems Division's training facility also has classrooms and a laboratory. The equipment is mobile so that the proper pieces of equipment can be moved in and out of the lab as needed.

II. CAM TRAINING

This section covers customer and employee training delivered by the Machine Tool, Industrial Robot, and Electronic Systems Divisions' training departments, all of which are part of their divisions' sales and service departments. While these training groups are primarily responsible for training customer personnel and CMI service representatives, they also provide training to other CMI research, development, and production employees. The majority of customer courses are delivered at the training facilities maintained by each training department. Training is also available at CMI technical centers across the country and can be delivered at the customer's plant.

Machine Tool Training

The North American Machine Tool Group has plants at the firm's Cincinnati, Ohio, headquarters, and at Wilmington, Ohio; Worcester, Massachusetts; and Fountain Inn, South Carolina.

The Machine Tool Group produces five lines of machining centers, three lines of CNC-controlled turning centers, six lines of grinding machines, and two lines of gantry-type profiler machines. All of these machines, with the exception of two grinders, are CNC-controlled. Thirty-eight of the 40 customer training courses currently offered by the Machine Tool Training Department focus on some aspect (programming, operation, or maintenance) of CNC machine tool systems. Approximately 60 percent of the 3,000 student weeks of instruction delivered each year by the Machine Tool Training Department is devoted to customer training; 30 to 35 percent is delivered to Machine Tool Division service representatives; and the remaining 5 to 10 percent is

provided to other CMI employees. Cincinnati Milacron service representatives and in-house production workers may take any of the customer training programs offered, and they may also take other technical training seminars open only to CMI employees.

Goals

The primary goal of customer training is to provide customer personnel with the skills required to program, operate, and maintain the systems and to repair them to the circuit board level. The standard courses are not designed to address specific customer applications, but rather to train the customers' employees to utilize the equipment safely and effectively. CMI considers that, since it is usually impractical for its trainers to learn the customers' applications in great depth, its best service to the customers is to provide them with basic machine knowledge and to allow them to refine the basic applications to their own needs. In some instances, however, CMI and the customer firm will establish training goals oriented toward a particular application and to the customer's employees specifically.

Training Staff

The Machine Tool Training Department staff consists of the manager of training, a training administrator, a registrar, and 16 full-time instructors. The manager of training, a B.A. in industrial management, has had experience as a production machinist and as an instructor in machine tools and weapons systems. Most of the instructors have industrial experience in programming, operations, or maintenance, or have been employed in maintenance positions in the Armed Forces. A number have also had formal teaching experience or experience on the shop floor as supervisors or on-the-job trainers.

Training Fees/Contractual Arrangements

In most instances four customer training slots are provided with the sale of each system. Occasionally, however, customers desiring additional training buy training slots or have training delivered in their plant for a fee. In some instances, training at the customer's facility is included in the equipment contract--usually when large numbers of systems are sold.

Customer Training

The amount and type of training normally provided to customer firms depends on the type of system purchased.

- o Classes in programming, operation, electrical maintenance, and mechanical maintenance are offered with the sale of machining centers and turning centers.
- o Classes in operation, mechanical maintenance, and electrical maintenance are available for purchasers of grinding machines.
- o Classes in CNC control maintenance, electrical maintenance, and mechanical maintenance are offered to purchasers of profilers.

The customer company may also contract for specialized training for its instructors and other employees or may buy extra student seats in any customer classes offered. Cincinnati Milacron suggests that first-time customers take advantage of the full range of courses offered for each machine in order to provide their employees with the skills required to maintain and maximize the utility of the system, but it is ultimately up to the customer how to allocate the training slots provided.

The courses provided to the purchasers of these systems are designed along occupational lines to provide specific instruction to workers or to the trainers of workers who will program, operate, and/or maintain the machines. The course descriptions which follow are from the curricula for vertical machining centers with CNC, but the course structure and many of the skill objectives are indicative of those of other machine systems training programs.

Programming. The objective of this course is to develop the students' understanding of basic programming functions relevant to the vertical machining centers, to develop the skills required for effective part programming, and to provide information about the machines' manufacturing capabilities. More specifically, the students learn programming formats,

coding methods, drilling, milling and boring programming techniques, circular helical milling, and tool-changing techniques.

The one-week course provides 32 hours of instruction (50-60 percent lecture; 40-50 percent practical laboratory experience) and has a normal enrollment of 10-12 students.

Operations. This course is designed to develop the students' understanding of operating procedures for vertical machining centers with Acramatic 900 controls (Cincinnati Milacron's brand of CNC controller) and of the operating capabilities and operational procedures of the Acramatic control. Specific skills training covers initial program loading, control set-up, editing, tool data management, machine set-up, and machine operation.

Instruction lasts for 1 week (32 hours) and is 30 percent lecture, 70 percent hands-on; the first day is primarily devoted to lecture and demonstration, and days 2 through 5 primarily to practical work on the machines. Since the course requires a great deal of individualized instruction and hands-on work, it is usually limited to six students per class.

Mechanical Maintenance. Course objectives are to provide instruction in disassembly and assembly procedures, preventive maintenance procedures, and machine adjustment; to present an overview of machine operating procedures; and to provide instruction in reading applicable hydraulic and electrical schematics. Students learn about the machining center system and control operation, and develop the skills needed to perform spindle-drive and slide-drive adjustments, mechanical adjustments, and preventive maintenance.

Like the operations class, this 32-hour course emphasizes hands-on instruction; students spend approximately 70 percent of their class time disassembling, assembling, and adjusting the machines to gain practical experience. The course is designed to accommodate 8 to 9 students.

Electrical Maintenance. This course develops the skills required to maintain and troubleshoot the Acramatic control, the D. C. drive systems and the interface between control and machine, and to present information on control and drive adjustments. Students in this 2-week course spend the first week at the Electronic Systems Division learning to maintain and troubleshoot the controller to the board level, i.e., to identify and replace a faulty circuit board. The second week--which includes instruction in slide drive theory, interface between control and machine, and spindle drive theory operation and adjustment--is delivered at the training facilities in Oakley. This 64-hour course is 50 percent lecture, 50 percent laboratory, and is usually attended by 8 or 9 students per class.

Prerequisites are listed for all of the courses. Operation courses, for example, require previous knowledge of NC machine tool set-up and operating procedures; various types of tooling, fixturing, and metal cutting technology; general machine shop safety procedures; and the ability to read "detail prints" and to read and use precision measuring instruments. It is the customers' responsibility to ensure that the employees they send to the training courses have the required basic skills.

Training Materials, including programming and service manuals and operator and instructor guides, are provided free of charge to each student. All courses include lectures supplemented by visual and audio-visual aids (overhead projections, slides, and sound/slide presentations) and practical experience on actual machines and controls or simulators.

Employee Training

Most employee training provided by the Machine Tool Training Department is delivered to customer service representatives, who may attend the customer classes, as well as basic skills courses and technical training seminars specifically designed to meet their needs. While most of CMI's customers require that their employees be trained in specific machine functions and capabilities, CMI's own service representatives--who install, test-run,

troubleshoot, and repair the machines at customer plants and often give on-the-job instruction to customer employees--must have in-depth knowledge of the entire machining system. The customer classes and employee courses often supplement each other in the training of service representatives.

Core Programs. One-to-two-week basic skills courses, called "core programs," are offered in the following topics: fundamentals of machining, grinding, electronics, turning, computers, and logic devices. A flow chart and catalog of course descriptions help supervisors determine the best training sequence for service representatives and other CMI employees. The availability of the core programs, the training sequence illustrated in the flow chart, and consultations with the training staff all help to avoid the major problem experienced in the customer classes--lack of prerequisite skills and knowledge. Service representatives who require it can also receive training in basic machine-tool operation courses delivered by the Corporate Training Department, or they may strengthen their skills through "field on-the-job training" (OJT), i.e., working in the customers' facilities with an experienced service representative. There is also the option of shop OJT, but this is unpopular with some floor supervisors, since it inevitably slows down production.

Technical Training Seminars. Presently, 9 "LEVEL I" seminars, each focusing on a specific machine line, are offered. The objective of the LEVEL I seminars is to develop in the service representative sufficient skills and information to set up, demonstrate, and maintain a particular machine system safely and effectively.

LEVEL II seminars, seven of which are currently offered, are designed to provide advanced skills to experienced service representatives to enable them to troubleshoot the majority of problems that can occur in the system. Prerequisites are up-to-date knowledge of computer fundamentals and of logic devices, along with completion of the LEVEL I seminar related to the specific machine system taught in the LEVEL II course.

The LEVEL II seminars range from 3 weeks (120 to 135 hours) to 5 weeks (200 hours). Most service representatives receive 13-15 weeks of training (both formal and informal) during their first year on the job and 4 to 6 weeks in their second year. After 18 months of field experience combined with training, most are prepared to install, set up, demonstrate, maintain, and troubleshoot advanced CNC machinery. Thereafter, the service representatives attend customer classes and/or technical seminars covering any new product they may be assigned to work on. The system is flexible enough that a trainee is permitted to take precisely those parts of the seminars which she or he needs to fill gaps in skills and knowledge.

Other employees of the Machine Tool Division may also attend both customer classes and the technical seminars designed for the service representatives. The selection of these employees--usually programmers, operators, and maintenance people--is the responsibility of their immediate supervisors. While they have the option of attending customer classes or technical seminars, most production department employees attend seminars or special classes modeled on the customer courses but open only to Cincinnati Milacron employees.

Evaluation, Certification, and Follow-up for Customers and CMI Employees

Training is primarily referenced by performance. Students are evaluated by means of written examinations; practical exercises; demonstrations of programming, operations, maintenance skills; ability to solve problems programmed into the machinery; class attendance and participation; and other criteria. Their overall performance is then compared to the required performance standards and rated on a scale from 1 (excellent) to 5 (fails to meet certification minimums). Instructors complete evaluation forms, and copies are sent both to the trainee and to his or her supervisor.

Trainees are asked to evaluate the course and the instructors in comparison to other training programs they have attended, rate the practical effectiveness of both, and give their own view of how the program might be improved. Cincinnati Milacron employees are evaluated on the same form used to evaluate the customers' employees. Like the customer classes, the seminars have performance standards to be met at the completion of the course.

Although there is no formal follow-up procedure, the Customer Service Department, of which the training group is a part, provides post-training assistance in two major ways. First, the training department will deliver additional training if required, often at no extra charge to the customer; and, second, practical on-the-job training is often provided by Cincinnati Milacron service representatives at the customer's plants.

Problems and Solutions

The most persistent problems arise with a small percentage of trainees, usually older machinists, who have extensive experience and skills with non-CNC equipment. They seem to fear losing control of the process when using the CNC machines, which require and permit less manual manipulation; some also have difficulties with computer-oriented terminology.

Instructors address these related problems by stressing that, while the students must learn to think more and act less than they did in the past, their knowledge of traditional machining operations will enable them to anticipate machine motions and functions once they become used to the controller and its operations. The instructors also emphasize that CNCs can give operators more and not less control of the machining process.

Due to the close student/teacher interaction, instructors are able to identify "problem students" early in the course. Generally it is possible to give individual attention and encouragement; on occasion, another instructor may be brought in to work on a one-to-one basis with an employee having difficulties absorbing the material. CMI tries to avoid this situation by encouraging the customer to send only those employees who have the prerequisites and who are open to receiving the training. Not infrequently, however, the customer firms either do not have employees with the required background and attitude, or, simply, they appear not to take CMI's advice. Often trainees become more comfortable with the machines once they are installed in the home shop; they can then be certified at a later date.

Industrial Robot Division--Robotics Training

The Industrial Robot Division is located in Lebanon, Ohio, approximately 30 miles from Cincinnati Milacron headquarters. A robot manufacturing plant is located in Greenwood, South Carolina.

Two sets of robotics training programs are offered: one series of courses on Cincinnati Milacron's line of hydraulic robots, and a similar series on the firm's newer line of electric robots. Both series contain two "core" modules--one on operation and "teaching," i.e., programming, and one on operation and maintenance. Supplemental courses in mechanical maintenance, welding, tracking, and controls are also offered on the hydraulic robots and are currently being developed for the electric robots. In the first three quarters of 1982, the division's trainers delivered 110 customer training courses.

Goals

The overall goal of the Robotics Training Department is to ensure customer satisfaction by providing the customers' programmers, operators, and maintenance personnel with a basic understanding of the system and the skills required to program and maintain the robots, utilize them to their best capacity, and to reduce down-time.

Training Fees/Contractual Arrangements

Customers receive two classes--one in operations and "teaching" and one in operations and maintenance--free of charge with each of the first three robots purchased. If 4 to 9 robots are purchased, a total of 7 student-weeks of training is provided as part of the equipment contract; a total of 8 student-weeks is provided with the purchase of 10 or more robots. Most customers request training for a second, and even a third, wave of employees after the robots have been installed. This training is delivered for a fee of \$900 per student week when conducted at CMI, and for \$5,000 per instructor-week east of the Mississippi or \$5,500 west of the Mississippi, then held at customer plants. For courses lasting less than 1 week, the cost is \$225 per student day.

Customer Training

The Robotics Training Department delivers approximately 25 percent of its vendor training at the customers' plants, largely because customers often recognize the need for further training (either more basic training for other employees or supplemental training on specific applications) once the robots are in place at their facilities. Whether classes are held at the CMI training center or off-site, the trainers attempt to keep the classes to a maximum of nine students to maintain an appropriate instructor/student ratio.

Core Courses

Operations and Teaching. The subject matter of this course is the functions of the robot and the specific details involved in "teaching" it to perform its task. The trainees are customer employees who will be responsible for robot programming. After an initial lecture on robot safety, students in this course learn to use the "teach pendant" to lead the robot through required sequences of movements; to produce and load systems tapes; produce, load, and verify data tapes; to recognize error codes and take appropriate action; and to teach, modify, and execute programs. The most important prerequisite for this course is a thorough knowledge of the process--welding, for example--the robot will be programmed to perform.

Operations and Maintenance. This course also includes operations, because workers responsible for maintaining the robots must be able to determine whether or not the system is operating correctly. Areas covered include installation procedures, basic operations, the control panel, tape loading, the hydraulic system, the electronic system, circuit board addressing and functions, troubleshooting, on-board diagnostics, the servo system, and procedures for interfacing the robot control to peripheral equipment such as motors and limit switches. Most of the time in class is spent on developing the skills required to troubleshoot the electronic system to the circuit board level, i.e., to remove and replace circuit boards safely and without causing damage to the board's components. This course is designed for engineers,

electricians, machine repair personnel, and group supervisors requiring general knowledge of maintenance operations. Prerequisites include the ability to understand and use oscilloscopes and digital voltage meters.

Each core course is 1 week (32 hours) in length and is approximately 40 percent lecture and 60 percent hands-on laboratory work. CMI supplies all classroom materials (manuals, programming exercises, and troubleshooting exercises) and also gives programming students "potted" programs to use in their home plants to test their own skills and the robots' functions. Both of the core courses are frequently attended by the customers' own instructors who will follow up with programs at their plants.

Supplemental Courses

The supplemental programs focus on specific programming applications and in-depth maintenance skills. The first three courses described below are delivered by the Robotics Training Department; the fourth is run by the Electronic Systems Division Training Department.

Mechanical Maintenance. Although this 20-hour course can be used to supplement the core courses, it is most often delivered as a stand-alone course for machine repair personnel. The training is mostly hands-on (60 percent) and consists primarily of dismantling and reassembling a robot. That prepares the trainees to be able to recognize mechanical problems and to replace faulty parts.

Arc Welding Applications. This 20-hour course addresses welding programming options that are beyond the scope of the core courses. Subjects covered in the lecture portions of the course (40 percent) include voltage, current, wire feed speeds, and specific arc welding applications. The remainder of the class time is spent in developing the students' skills in such areas as programming the special velocities required, performing associated maintenance procedures, laying down welds, and setting up the weld controller.

Line Tracking. The 20-hour Line-Tracking course focuses on programming a robot to follow a moving conveyor line. Thirty percent of the class time is

devoted to lectures on the principles involved in the tracking operation and on the mechanics of programming, and the remaining 70 percent is spent in practical laboratory application work.

Robot Controls. This 2-week course on robot controls' devices trains maintenance electricians in the skills required to do in-depth troubleshooting of the robots' electronic hardware. The trainees are taught the diagnostic abilities of the robot's software in order to use that software as a tool to troubleshoot the hardware.

Employee Training

Because most Robot Division service representatives are experienced field personnel and many have transferred from the older Machine Tool Service Department, there is little need, at present, for the basic skills courses described on pp. 11-13. Robot Division service representatives attend both of the core robotics courses as well as the 2-week controls course in order to learn to program, demonstrate, and repair the systems.* This coursework is supplemented by on-the-job training in the field and by one or more of the supplemental courses. Other CMI employees attend those courses suited to their specific needs--an applications engineer, for example, may attend the core course in programming and operations and the supplemental courses in welding and tracking.

Evaluation, Certification, and Follow-up

While the evaluation and certification forms and procedures are almost identical to those used by the Machine Tool Training Department, the Robot Division is developing a more formal follow-up procedure than that used by the other training departments. Future trainees will receive follow-up forms 3 months after the training program on the theory that, by that time, the trainees will be well-versed in their own specific applications, will have encountered applications problems, and will be able to articulate constructive criticism of the training.

* Robot Division service representatives differ from the customer trainees in that they have all the prerequisite skills.

Because the Robot Division conducts a great deal of follow-up training, the instructors have the opportunity to track past trainees and to evaluate previous training on an informal basis. Examples of curricular changes made in response to this informal follow-up and course evaluation include more attention to skills and information tailored to the students' specific needs and more emphasis on hands-on training.

Problems and Solutions

The majority of robotics trainees who do not have programming backgrounds begin their training with some anxiety about working with robots. Trainees often come to class thinking of the robot as an antagonist. In its casing, it is an unfamiliar-looking piece of equipment; furthermore, it is expensive (\$60,000 to \$120,000) and many trainees fear that they will damage it. Added to this is the trainees' fear that they will ultimately be displaced by the very machine they are being trained to maintain. These anxieties are so commonplace that the instructors deal with them at the first opportunity. First they explain to the trainees that being in a robotics training class strongly suggest that they are the workers with the least likelihood of being displaced. They then describe the machine and its parts and functions, many of which are similar to those of equipment with which the students are familiar. Then they instruct the students in the use of the "teach pendant." All of this occurs on the first day of the class, and once the students have had the opportunity to work on the robot and to do some basic programming, most begin to see it as a tool and even as a partner.

Another problem similar to that experienced in machine tool training is that a number of the trainees come to classes without some of the prerequisite skills. The interim and partial solution arrived at by CMI instructors is to include more basic hydraulics and electronics in the core maintenance course, but this means that the time must be taken from other topics, and that those students who do have the basic skills and knowledge are disadvantaged. Since, however, CMI defines its role as the provider of machine-specific training (not basic skills training), a more desirable outcome would be for customers to become more aware of this and be willing and able to provide basic skills training in hydraulics, electronics, and oscilloscopes.

Electronic Systems Division—Machine Control System Training

The Electronic Systems Division is headquartered in South Lebanon, Ohio, approximately 30 miles northeast of Cincinnati.

The Electronic Systems Division (ESD) produces machine control systems, most of which are used to control Cincinnati Milacron machine tool and robot systems. Some, however, are marketed separately under the corporate trade name of Acramatic. ESD's training group thus coordinates its services with robotics and machine tool training and also provides instruction to customers who purchase only the control systems.

The ESD group is the oldest customer and service training department at CMI, having initiated its customer training in 1960. Since, however, ESD serves the Machine Tool and Robotics divisions as, essentially, an Original Equipment Manufacturer (OEM) supplier, its volume of training delivery is less than that of either the Machine Tool or Robotics training groups; in the first three-quarters of 1982, ESD conducted 65 classes serving 570 students (350 customers and 220 CMI employees).

Goals

The controls courses are designed to serve the needs of two major groups: customers and CMI service representatives. The major goal of the customer training courses is to reduce the customers' dependence on ESD field service representatives by developing the skills of their service personnel to the point that they can isolate and repair 80 percent of control hardware malfunctions within 24 hours. The primary goal of the service representative training is to increase the technical effectiveness of the field personnel.

Other employees of the Electronic Systems Division may also take the service representative courses. The goal in reference to these employees (primarily engineers and production workers) is to increase their technical skills and their knowledge of control systems.

Training Staff

The staff consists of a training manager, a registrar, a coordinator and eight instructors. One of the instructors also serves as a curriculum developer for employee courses, while the other seven devote part of their time to developing new customer courses. The majority of the instructors have industrial backgrounds as electronic technicians (Associate degree level) or electricians with shopfloor experience, while the others were recruited from educational institutions (B. Ed. with coursework in electronics). This mix of industrial and educational expertise enables instructors of different backgrounds to learn from each other and to achieve a blend of technical knowledge, industrial experience, and instructional skill.

Training Fees/Contractual Arrangements

One student seat in a basic controls course is provided with the sale of each machine tool system. ESD also offers basic and advanced APC courses for \$550 per week for each student. The charge for an instructor to deliver training in a customer's plant is \$5,000 per week. This fee usually includes manuals and other supplies and instruction for 8 students.

Customer Training

Four Level I (basic) and five Level II (advanced) courses are available to Cincinnati Milacron customers. The Level I courses include a 1-week course on the Acramatic Programmable Controller (APC) and 2-week courses on the Acramatic CNC, the Acramatic 900 Version 1, and the Acramatic 900 Version 2. The latter three controls are standard equipment on various Cincinnati Milacron machine tool systems. Customers purchasing these systems attend control classes at ESD for the first week of training, and spend their second week at the machine tool training facility learning drive theory, operation, adjustment and the interface between the control and machine. All instruction in the APC course is delivered at the ESD facility.

The Level II customer courses are 2 weeks in length. Four of those courses are advanced versions of the Level I programs and the fifth is the advanced course in robot controls.

Aside from the APC programming courses, which were developed to serve design engineers, the majority of controls courses are designed for workers involved in electrical maintenance and are attended by electrical maintenance technicians, electronics technicians, and associate-degree technicians.

Approximately 5 percent of the students are managerial and supervisory personnel, most of whom take the APC course to develop an awareness of the capabilities of the system.

Course Design and Training Methods. Level I courses on the machine tool's control system all focus on the functional operation of the control, diagnostics, and troubleshooting and maintenance of the control. The Level I APC training includes both programming and maintenance, while the three Level II APC courses deal with 1) advanced programming, 2) advanced maintenance, and 3) higher level language programming.

Students in the basic maintenance classes develop the skills to troubleshoot the controls to the circuit board level, while advanced students learn to troubleshoot the equipment to the level of the circuit itself.

Classes range in size from 8 to 12 students, with 8 considered optimum. The classes are approximately 50 percent lecture, 50 percent laboratory work. Laboratory work is used as a reinforcement of the lectures, and all courses are structured with a morning session and an afternoon session, each consisting of 2 hours of lecture followed by 2 hours of lab. Additionally, there are homework assignments and daily quizzes.

Employee Training

Unlike the Machine Tool Division training department, ESD's training group maintains a strict separation between customer classes and employee classes. The ESD trainers have found through experience that Milacron service representatives are so much more familiar with the CMI systems than customer employees that the two groups require a different level of teaching, both in the basic and advanced classes. ESD feels also that 2 weeks of training is not enough to develop the skills needed to train controls service personnel. However, because customers cannot usually spare their personnel longer, ESD

has truncated the customer courses to 2 weeks. It provides its own employees with 3 to 4 weeks of training. ESD service representatives also take some of the technical seminars delivered by the Machine Tool Training Department.

Employee courses lasting from 3 to 4 weeks are offered on each type of control system manufactured by CMI. More time is spent on the software portions of the control than in the customer classes, and CMI service representatives are trained to troubleshoot the 20 percent of malfunctions that are beyond the scope of customer training. CMI employees may also take an array of 1-week ESD courses dealing with the functional blocks that make up the CNC systems. These include courses on the microprocessor, on the computer itself, assembly language, and an in-depth course on the servo system.

Evaluation, Certification, and Follow-up

These procedures are similar to those in the machine tool and robotics training departments.

Problems and Solutions

Because electronic controllers have been in use for over 20 years, the vast majority of the students in ESD's courses have the skills and experience required as prerequisites for the controls courses. The training manager, who has been with the controls training group since the early 1960's, reports a palpable increase in the level and skills of the customer students during his tenure. Consequently, few, if any, students in the controls courses experience the anxiety or resistance exhibited by many robotics trainees and some CNC machine tool trainees.

Special Customer Training Arrangements

All of the training departments have conducted specialized training for large volume customers. Often the training delivered in these circumstances involves cooperative efforts by two of the departments, and sometimes by all three. Large volume training projects are often structured along the lines of the following model:

1. Instructors from the customer firm attend customer training classes at CMI, often attending courses two or three times to develop instructional skills as well as operational ones.
2. CMI instructors travel to the customer's plant to deliver, with the assistance of the customer's own training staff, training which is often tailored to the customer's specific manufacturing processes.
3. The customer's instructors then take control of the training; sometimes this is under the observation of the CMI trainers and sometimes with a CMI trainer or service representative on call to answer questions or assist with special problems.

In practice, variations of the above model occur. The examples that follow describe a few of CMI's customized training arrangements.

Hydril Retraining Program (Machine Tool Training)

In January 1982, the Tubular Products Division of the Hydril Company, the world's largest producer of connections for oil field casing and tubing, took the first step in implementing its decision to change its plants over to CNC equipment and to automatic storage and retrieval systems. Hydril interviewed three vendors and told each that a major determinant of the contract award would be the machine tool firm's ability to deliver training that would meet Hydril's specifications. CMI was awarded the multi-million-dollar contract for 106 CINTURN's, CMI's brand of CNC turning centers.

The training specifications were developed in consultation with CMI by the Hydril training department and Industrial Training Group, a management/training consulting firm. The courses were modeled on a performance-based training system that the Industrial Training Group had recently designed for Hydril employees working on non-CNC machines. The specifications for the CMI training called for performance-based training that is task-oriented, learner-paced, and modular in form. Specified training materials included video modules with interactive workbooks, job-performance guides, detailed instructor manuals, and certification checks for each task.

The specifications further required CMI to perform a detailed task analysis (necessary for the development of job performance guides) and to guarantee that at least 90 percent of the Hydril trainees be able to perform at least 90 percent of the tasks during the hands-on certification checks.

Apart from the requirement discussed above, CMI agreed to deliver 500 student-weeks of training to Hydril employees. (That represents less than 500 people trained, since some employees take more than one course.) The training was designed to be delivered in two phases, each described below:

Phase I. Training in this phase was conducted from June through December 1982 at Cincinnati Milacron's Ohio training facilities by the Machine Tool and ESD training departments. CMI instructors used tailored versions of the standard CINTURN programs (similar to those described on pp. 9-11) to train Hydril programmers and operators. More comprehensive training, which also included CMI CINTURN maintenance courses, was delivered to plant supervisors and managers, maintenance and production managers, foremen, and first-line supervisors to help them prepare their operators and maintenance personnel to work with the new equipment. The most comprehensive training was given to Hydril instructors, who were trained to understand the machine system as a whole as well as its specific programming and operation functions and mechanical and electrical maintenance requirements. After they received the CMI training, Hydril instructors worked in teams with Cincinnati Milacron instructors to deliver operator training courses to Hydril employees. At the same time, the CMI Machine Tool Training Department conducted the task analysis, developed the video modules and interactive workbooks, the job performance guides, and the customized performance-based training to be delivered in Phase II.

Phase II. When Cincinnati Milacron delivers the customized training packages to Hydril, all training will be transferred to Hydril facilities and all training will become the sole responsibility of Hydril instructors. Until that time, CMI instructors will provide training assistance.

GMC Truck and Bus Robotics Training Programs

The Industrial Robot training department delivered in-plant training to the General Motors "S" truck plant in Moraine, Ohio. As part of the equipment contract for 27 robots, CMI trained 29 GM employees in November 1980 and provided the full-time services of a field service representative for three months following the installation. According to the Moraine GM representative, the presence of the service representative, along with the exposure and knowledge from the classes, gave the GM workers the experience and the confidence they needed to solve the initial application problems and to handle the majority of troubleshooting problems.

Whereas the Moraine "S" truck plant has a stable work force, the work force at the "S" truck plant in Pontiac, Michigan, is constantly changing because of worker flowthrough agreements with other nearby GM plants. The Pontiac plant management therefore decided to set up an ongoing program of in-plant training. Cincinnati Milacron's role in helping to implement that training is discussed in detail in the GMC case study, #2.

International Harvester--the Systems Approach

International Harvester's purchase of 10 robot-CINTURN cells (manufacturing systems comprised of two CINTURNS and a robot for loading and unloading) triggered the one training effort to date involving all three customer training departments. The CMI customer training departments trained more than 150 International Harvester employees over a 6-month period.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY

Summary

CMI has well-equipped facilities and a highly skilled and experienced staff of trainers, and it has exhibited a high degree of commitment of human and capital resources to the delivery of training on computer-aided manufacturing equipment. Currently, the training is delivered by independent specialist groups representing the production divisions. This assures, in most cases,

that the sub-topics of training will be treated by the instructors who have the greatest depth and expertise. While the delivery of skills development training is adequate under the existing system, rapid developments in both the inherent technology of the subsystems and the prospect of integrated flexible manufacturing systems suggest that training may be becoming progressively less amenable to the present degree of independence of the training divisions.

An additional effect of the technology explosion and the systems approach to manufacturing is the gradual shift in training away from the broad "generalist" approach which has characterized CMI since 1906. Future training capacity will be affected both qualitatively and quantitatively by the rapid developments in products and processes. The problem is recognized by management at CMI and steps are being taken to address the question of the optimum degree of independence and interdependence of manufacturing and training operations of the company's operating divisions. The evolution in product and process technology has affected training for both employees and customers. Specific considerations for each of these groups are considered below.

Employee Training

Changing economic and social conditions, characterized by layoffs, hiring freezes, and increased mobility of employees, along with the constant introduction of increasingly sophisticated computer-controlled machinery, have necessitated modifications in the content and pattern of employee training.

There is now more specialized training in CAM equipment and less general skills training. Some of the management and professional-level employees feel that the reduction of the one-time 8,000-14,000 hours of training in the full range of company operations has reduced the capacity to generate adaptable, flexible employees, well trained in basic skills. These same employees, however, recognize the need for increased depth and specialization in workers' capabilities, paralleling the ever-increasing complexity of the CAM equipment they must deal with. It is estimated that some 1,000 hours of general training time is saved by the use of videotaped demonstrations, and the company will explore computer-aided instruction delivered on the shop floor to supplement, but not necessarily replace, some of the classroom and on-the-job training.

The development of CAM and robotics and the skills required for their use and maintenance provided the original need for customer training at CMI. The firm began providing customer training along with those sophisticated controls and NC equipment. Increasingly, the in-plant training of CMI employees is also being delivered by the customer training departments, especially ESD and MIL, which have expertise in specific systems. As a result of the focus on machine-system-specific training, the customer service training departments have developed the expertise which is now needed for the training of CMI employees as well. An additional contribution of the customer training program to the overall CMI training picture could be the development of improved training processes based on what is learned from delivering special training in the customers' plants.

Training for Flexible Manufacturing Systems Skills. CMI has been addressing the problem of encompassing the present and future need for frequent skill updating, while maintaining an integrated, coordinated training program that provides both basic skills and familiarity with the overall operations of the firm. In the future, a manager may not need to undergo a series of training programs in several departments to become fully conversant with the production requirements. The central, computerized control and monitoring capabilities of the systems approach and the information-sharing capabilities of the central data base pose a new challenge for training design and implementation. In the "flexible manufacturing facility" of the near future, the training of managers is most likely to focus on the entire integrated design-and-production process.

CMI is now developing a training concept for shopfloor, technical, and management level employees that is appropriate to its new "variable mission" manufacturing systems. The initial proposal is to make use of the existing customer-service training departments to provide supervisors and foremen with the skills and knowledge required to understand and manage the overall manufacturing process.

Some of the Corporate Personnel Development Department's initial ideas on training requirements in a flexible manufacturing environment include the following:

- o More "process-type people" who are knowledgeable about manufacturing engineering, manufacturing processes, CNC programming, and related skills will be needed. This entails a shift in skills training from the traditional milling, drilling, turning, and grinding machine operator skills training to planning, CNC programming, and CNC maintenance training.
- o The number of employees who will be directly involved in manufacturing will decrease, while the number required for indirect support--programmers, process engineers, system software developers, and mechanical electrical maintenance personnel--will increase. The corporate training department proposes a workforce planning study with appropriate recommendations for recruitment, training, and retraining.
- o The new skill and workforce requirements entail new training procedures. In CMI's view, the manufacturing supervisor, who should have in-depth knowledge of machining and manufacturing processes, should be trained in the overall operation of the system. The proposal is that this be done by the Variable Mission Manufacturing group and/or Manufacturing Systems Division. Training for others involved in programming, operations, and maintenance should be broken down into small units and be delivered by the existing customer training groups. The Corporate Personnel Development Department would coordinate and oversee the entire systems training effort or would suggest the creation of a systems training group to so coordinate.

Customer Training

According to the three CMI customers interviewed for this report, CMI course content and training materials were clear and well-organized, the delivery was effective, and the training met the stated objective of providing knowledge of the systems and an overview of the skills required to program, operate, and

maintain them.* Both CMI and customer representatives point out, however, that such 1- to 2-week training courses can present only an overview and develop the basic machine skills required. The real training comes with on-the-job experience after the systems are installed. CMI's readiness to serve its customers by providing ongoing assistance by service representatives enhances its training capacity by providing for on-the-job service and training assistance while the customer personnel are gaining on-the-job experience. The availability of special training arrangements also enables CMI to help customers implement their own training programs on CMI equipment.

Such special training arrangements are indicators of CMI's flexibility and responsiveness to its customers' training needs. An added benefit is the increased applications knowledge and feedback CMI gains from specialized training, which is often delivered at the customer's plant in conjunction with the plant training staff. The Hydril training project, for example, will result in a library of interactive video modules which will be adapted by MTU for future training purposes and the possible implementation of performance-based training techniques in the classes delivered by the Machine Tool Training Department and other CMI customer training departments.

Overall Future Training Considerations

In the future, increased use of flexible manufacturing systems may impel changes in coordination responsibilities of the training departments within the overall corporate structure.

- o Although training is now available on the individual products or the divisions of CMI and cooperation among the training departments is high, when more of the integrated systems are marketed, there is the potential for some conflict over matters such as development of overlapping expertise in several divisions and scheduling of training delivered by two or more customer training departments. To insure increased coordination in the future, the managers of the

* Of the three firms interviewed, two were customers of the Robot Division, and one a Machine Tool Division customer who had also received ESD training.

customer training departments have begun to hold regular meetings in which they discuss common training needs and techniques, current projects, and methods of coordination. The Corporate Personnel Development Department's suggestion--to institute a systems training group and/or coordinating unit--is another possible solution to future coordination problems.

- o Another consideration for the training planners is the mix of tailored v. standardized programs. While the tailored programs have led to a deepening expertise in the individual training departments and are better suited to the customers' needs, they are more expensive and, by definition, less replicable than standardized courses. An additional advantage of standardized programs is that they can be (and most often are) delivered to employees from a mix of companies; this gives the students the advantage of being able to talk to others who work on different applications and have different problems, and therefore provides them with a wider range of exposure than they would receive if they attended classes with only employees from their own plants.
- o CMI is stressing performance-based training. This in itself may help to solve some of the questions related to the mix of standardized and tailored training delivery. If performance-based training--which involves detailed task analysis of the customers' operations and a one-to-one match between the workers' tasks and the goals of the training program--is adopted as a primary training delivery method by CMI trainers, they will have a training method which is replicable while the specific content of the training will be geared to the customers' needs.

All of the customer training departments covered in this report are developing methods to increase the self-sufficiency of their customers. LSD is considering the development of video cassettes that would enable customers to review and reinforce the training at their own plants; the Robot Division is working on applications courses built around practical exercises focused on

specific, real-world tasks; and MTD is actively working to make the performance-based training model described under the Hydril project a corporate-wide training method.

The move to performance-based training may give CMI the ability to serve its customers and its employees in a wider capacity than is now possible. It would enable the training departments to become "performance analysts" as well as trainers who could deliver training that is not only precisely suited to the customers' operations, but which could also be converted into tailored training package for use by the customers' instructors at their home plants.

In a wider context yet, an important opportunity for Cincinnati Milacron to participate in community training efforts arose in October 1982, when the firm was requested to participate in a proposed national demonstration project initiated by the General Electric Company's Aircraft Engine Business Group and the Greater Cincinnati Area Private Industry Councils and CETA Prime Sponsors. The demonstration project would create a non-profit "Greater Cincinnati Industrial Training Corporation," which would develop a set of 56 courses with more than 110 video lessons in industrial machining and fabrication. These would be used to upgrade the existing workforce and to train CETA-eligible individuals and "high risk" high school students in the machining and fabrication fields. CMI will participate in this program, and its corporate training manager will encourage the project directors to emphasize the development of the skills required to operate, program, and maintain computer-controlled machining equipment.

In another outreach activity, CMI's Corporate Personnel Development Department has suggested to state officials that CMI and other companies work with the State to organize a consortium within the State Vocational School college and university system whereby one or more schools would be designated to provide instruction and skills training in up-to-date manufacturing technologies. CMI and participating companies could assist that school with curriculum planning and development, instruction, and equipment in addition to coordinating the instructional program. This plan, or one like it, would not only help to solve the retraining problem, but it would also help the schools to update their course offerings and equipment.

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At the broadest level, Cincinnati Milacron--with its long and varied experience in traditional skills training, and its more recent experience with CAM skills training--is in a position to apply its expertise in assisting solving the problem of retraining some of the nation's workforce--specifically to those workers within the State of Ohio.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

VOLUME II - WORKING PAPERS

Part C - Individual Education and Training Case Studies

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OFFICE OF TECHNOLOGY ASSESSMENT
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COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.2— General Motors Truck and Bus “S” Truck
Plant, Pontiac, MI: “New Technology Training”**

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI:
"NEW TECHNOLOGY TRAINING"

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI

"NEW TECHNOLOGY TRAINING"

BACKGROUND/SUMMARY

The "S" truck plant, in Pontiac, a northern suburb of Detroit, is one of three GMC Truck and Bus Division facilities that produce the new compact "S" truck line. Operating on a one-shift basis, the plant produced 61,647 trucks in the 1981 model year. In October 1982, the plant moved into a double shift operation and now employs approximately 1,700 hourly workers, including 200 maintenance workers, of whom 70 are electricians responsible for maintaining and repairing the 43 robots and approximately 100 programmable controllers installed in the facility.

"New Technology Training"

In the late seventies, the division produced "G" vans at what is now the Pontiac "S" truck plant. In 1979, when rising gasoline prices and a consequent drop in van sales and orders caused the closing of the "G" van operations at the plant, a handful of managers, engineers, and supervisors remained to evaluate possible new products and to determine the most efficient means to get the facility back into operation. When the new "S" truck project was assigned to the plant, in March 1980, it was decided that productivity and quality would be increased by installing a line of welding robots and expanding the number of programmable controllers from 5, in the "G" van production, to the nearly 100 now in use on the "S" truck line. The plan to install the computer-aided machinery presented the team of managers and engineers with a further decision—how to retrain the laid-off workers who would be recalled to work on "S" truck production. After considering various options—training by machine vendors, courses at community colleges, commercial training packages—the plant management chose in-plant training as an economical and efficient means of getting the recalled workers "out of the technology of the sixties and into the eighties" in the shortest period of time.

In-plant training began in 1980 with the installation of the first Cincinnati Milacron HT3 robots and Allen Bradley programmable logic controllers (PLCs)*. In its 2 years of existence, the "New Technology Training Program" has expanded to over 40 courses—including a variety of machine-specific courses on robots, programmable controllers and special machines like tire mounter/inflators; upgrading courses on pneumatics and hydraulics; courses on weld quality and technology; and occasional courses on robotics for management-level employees. As of October 1982, a total of 900 workers had received "New Technology Training" (this represents fewer than 900 people, however, since some have taken two or more courses). The number of robots installed in the plant has grown from an initial 24 to 43, and the Allen Bradley PLCs now control spray painting operations and conveyor, assembly, shuttle, lift and carry, and automatic welding systems. According to the plant superintendent of maintenance and tooling, who initiated and still directs the training effort, "new technology training is crucial to the efficient operation of the plant. In his estimation, the sophistication of the new machinery, and the high costs incurred when the machines are not well-maintained and repaired quickly when they break down, make in-plant training "a must."

Among the many side benefits of the training is the use of the training laboratory area as an applications lab. Shortly after the training started, the trainers discovered that the robot set up in the lab could be used to test installation requirements and welding applications, and that the controller could be used to test printed circuit boards before they were mounted in the controllers on the plant floor. The controller is now in use 24 hours a day either for training or testing purposes or to "burn in" new circuit boards before they are installed in production equipment.

* The HT3 is one of Cincinnati Milacron's hydraulic robot models. Programmable Logic Controller (PLC) is Allen Bradley's trade name for its line of programmable controllers.

ORGANIZATIONAL VIEW OF TRAINING

Corporate Resources

GMC has a corporate level education and training department, one of whose functions is to serve as a resource to the divisions and their plants. A further corporate resource is the GM Tech Center, which provides the divisions with assistance in new technology applications. However, since the training needs of each GM division and, indeed, of individual plants within each division, vary widely, the divisions, as well as most plants within each division, maintain independent education and training departments and have a great deal of latitude in the operation of specialized training programs, such as the New Technology Training Project at the Pontiac "S" truck plant.

New Technology Training at the Pontiac "S" Truck Plant.

The new technology training group was located in the maintenance department, whose function it is to serve the maintenance and repair needs of the production departments. To ensure that all those responsible for the efficient operation of the computer-aided equipment were trained in the general theory, operation, and maintenance of the robots and programmable controllers and were equipped to deal with the specific machine applications required by "S" plant production, the maintenance department set up an ongoing program of in-plant instruction. Technical assistance was provided by the GM Tech Center robotics staff; and the corporate Education and Training department and the plant manager for education and training were on hand to advise on training techniques.

The plant management placed the training function in an operational department for a variety of reasons. In the first place, the maintenance department had technical expertise with reprogrammable equipment which was lacking in the training department. Secondly, by giving the maintenance department the responsibility for training and by setting up the training facilities in the departmental offices adjacent to the production facilities, potential problems involving scheduling and coordination between departments were eliminated or reduced. Thus, the maintenance department could coordinate training schedules with operational schedules and be certain that the trainees would receive instruction precisely suited to their responsibilities on the job.

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The decision to deliver the training on-site in the plant not only gave the maintenance department control over the content of the courses, but also allowed for a great deal of flexibility. Over the 2-year period of its operation, this flexibility has enabled the maintenance department to address numerous training-related concerns--the necessity of providing continuous training to accommodate the extensive turnover in personnel (caused by workers exercising "shift preference" rights who "bump in" to the Pontiac plant*); the need to institute new courses in specialized machines or testing equipment; the provision of machine safety courses for workers who work around, but not with, the new equipment; and seminars for managers to give them an overview of robot functions and training requirements. The in-plant training lab also provided the maintenance department with the opportunity to pre-test robot installation and application requirements.

From its inception, the new technology training project was seen by plant management as crucial to the plant's production capacity; by meeting the training needs of the workers who maintain the production equipment, the program would serve the quality and production requirements of the plant. According to those involved in the training effort, the installation of the computer-aided manufacturing (CAM) equipment made specialized training a necessity, not a luxury, in the Pontiac "S" truck plant. It is no longer possible, they say, to "get by" without specialized training beyond the apprentice level.

NEW TECHNOLOGY TRAINING PROGRAM

Goals

The original goal of the program was to train the plant's maintenance workers in the skills required to keep the reprogrammable equipment operating at peak efficiency. The major goal of the training program was therefore intimately

* Workers with seniority have "shift preference;" that is, if they are working on a second or third shift, they may move to a preferred first shift in any plant in the Truck and Bus Division by replacing a worker of lower seniority. They thus "bump in" to jobs previously held by other workers. The low seniority worker then moves to another shift in the same plant or to another plant in the division.

linked with the management goal of producing a quality product in the most efficient manner possible. As the training expanded to include more courses, additional objectives were added. These include the provision of upgrade training in hydraulics and pneumatics to maintenance workers not responsible for reprogrammable equipment; safety training for some who work in the vicinity of robots; robotics training for non-electrician maintenance workers (when schedules permit and when training slots are open); and management seminars in robotics.

Program Start-Up

The initial training courses in robot and PLC maintenance and operation were delivered at the "S" truck plant by the vendors of the reprogrammable equipment. PLC training was provided by Allen Bradley; and Cincinnati Milacron (CMI), ASEA and Prab delivered courses on the operation and maintenance requirements of their specific robot systems. These initial customer-training courses were attended by the GM trainers, applications engineers, supervisors, and hourly maintenance workers (who made up approximately two-thirds of the initial trainee group).

Cincinnati Milacron--Training the Trainers

Since CMI supplied the majority of the robots at the "S" truck plant, special training arrangements were made with the robot-producing firm.* Before the installation of the first Cincinnati Milacron HT3 robot, two GM trainers and two applications engineers attended CMI's basic customer courses in Cincinnati, Ohio (see case study #1). When the first HT3 was installed in the "S" truck training laboratory, CMI trainers traveled to the Pontiac plant to deliver the first in-plant program for GM maintenance workers, engineers, and shop floor supervisors. The GM trainers assisted the Cincinnati trainers in this first in-plant course and later delivered the Cincinnati course while the CMI trainers observed and assisted when necessary. While some modifications were made to the Cincinnati Milacron course to tailor it to GM's specific application needs and worker requirements, the CMI course remains the staple of most of the robotics training at the "S" truck plant.

* CMI also produces a large line of computer-controlled numerically controlled machine tools (see Case Study #1).

Other Vendor Training

Customer training provided by the other equipment vendors occurred after the Cincinnati Milacron training and was less extensive than that provided by GM. After one in-plant training session each by Allen Bradley and ASEA, the GM trainers were ready to deliver training on the equipment produced by those firms. Since the Prab robot is less complex than the others and relatively easy to operate and maintain, the head trainer at GM was able to design the in-plant course on the Prab after attending one customer training course at the Prab training facility.

Applications Lab

A significant aspect of the initial few months of the new technology training was the discovery that the classroom laboratory could also be used as an applications laboratory. Applications experiments began when the maintenance supervisors, trainers and some maintenance workers who had received initial training used the robot installed in the classroom to test their ideas for mounting the weld guns that would be attached by the production robots. After designing special brackets for mounting the weld guns and a breakaway clutch that would shut down the robot in case the weld tips stuck to the cabs, they began developing a welding hose specifically adapted to the robots' movements and experimenting with designs for attaching the power cables and weld transformer to allow for the greatest freedom of movement without entangling them with the robot arm. Once the outfitting applications were designed and tested, the maintenance staff began using the trainer robot to test each weld gun that would be attached to the robots on the production line. They then set up a truck cab in front of the classroom robot to help them predetermine the welding schedule and to test the proper position of the robot relative to the cab for each welding application.

This two-to-three month period of testing helped to avoid costly installation and application problems with the production robots. Now, 2 years after these initial experiments, the classroom equipment still serves multiple functions. When the PLC "teach console" is not being used for training, it is used to test and "burn in" printed circuit boards for 200 hours before they are used in the PCs in the plant.

Staff

The superintendent of maintenance devotes approximately 5 percent of his time to administering and overseeing the training.* One maintenance supervisor is assigned full-time to training and related R & D duties; two other maintenance foremen teach occasional classes, and another foreman will soon be assigned to training.

An important consideration when setting up the training program was whether to choose educators or technicians as trainers. After conducting an informal evaluation of the merits of each group, the maintenance supervisor determined that it was easiest and most productive to find technical personnel with leadership abilities and to train them in instructional techniques. Accordingly, the chief trainer is a shop floor supervisor with previous experience as a journeyman electrician. The other two foremen who provide training support are journeymen (one an electrician, one a mechanic) who had been promoted to the supervisory level.

The director of the training project, the superintendent of maintenance, has 13 years of experience at GM and is certified by the Society of Manufacturing Engineers (SME) as a robotics engineer. He is also co-chairman of the GM Corporate Robotics Council Training Task Force, a member of the council's Safety Task Force, and a member of the Education and Training Committee of Robotics International of SME.

Facilities and Equipment

The classroom/laboratory occupies 792 square feet of space adjacent to production facilities in the "S" truck body plant. Current equipment used in robot and PLC classes includes a Cincinnati Milacron HT3 robot, an ASEA IRB 60 robot, four oscilloscopes and an Allen Bradley programmable controller teach console (especially designed to simulate most of the floor conditions at the plant) with two CRTs.

* Initially, when the training was being developed and refined, the maintenance superintendent spent approximately 20 percent of his time on the training effort.

Training Costs

Training costs are provided for in the maintenance department's budget. Most program costs, however, were not available. It is estimated that a 5-day training course with an enrollment of 10 journeymen costs the maintenance department \$1,000 in written materials and \$4,000-5,000 in wages for lost work time.

Trainee Selection Criteria

Since the object of the program is to provide training for the plant's maintenance staff, all maintenance electricians are scheduled for courses in robotics, programmable controllers, or both. While the vast majority of trainees have been electricians, other maintenance workers (machine repair personnel, millwrights, pipefitters) and in-house industrial engineers have also taken robotics and PLC courses. All of the plant's workers receive quality-of-work-life training sessions (basically, an orientation to the plant) and training in plant safety. These sessions are delivered in the maintenance department's training facility and coordinated by a trainer from the plant's production department.

Aside from the maintenance electricians, all of whom receive robot or PLC training, the choice of which maintenance workers receive specialized equipment training is the responsibility of the maintenance department. Selection in these instances is made on the basis of job assignment (i.e., those workers assigned to maintain machines requiring special knowledge or skills are scheduled to receive the required training). A similar selection procedure is followed for production workers who receive special training: those who work in the vicinity of robots take short classes in robot safety; those who work with complex new equipment are trained to operate that equipment.

The union local does not directly participate in the selection of trainees. For a discussion of the union's involvement in the training, see p. 21.

Class Size

Although class size varies, depending on the complexity of the course material, most classes are kept to a maximum enrollment of 10 trainees.

Training Courses

Over 40 courses--ranging from 1-hour sessions in robot safety to 40-hour operations and maintenance programs on specific equipment -- are delivered on an "as-needed" basis. A condensed listing includes courses in robot and PLC maintenance, operation, and programming; pneumatics theory and operation; basic hydraulics; weld controls; weld quality and technology; hydrostatic drive theory; and automatic spray painting operation. By far the most frequently offered courses, however, are basic maintenance/operations courses on the Cincinnati Milacron HT3 and the Allen Bradley PLC-1, PLC-2, and Mini-PLC. At present, one course on HT3 maintenance and operations and one PLC course are given each month, while other courses are scheduled as needed.

Sample Curricula

Robotics

The HT3 maintenance/operations course is one of five robotics courses delivered by the new technology training group. Two other courses are given on the HT3: "Robot Mechanical HT3," which involves disassembling and reassembling the robot to provide in-depth skills-training in mechanical problem recognition and parts replacement; and "Robot Programming HT3." The other two courses cover the functions, operations, and maintenance of the ASEA IRB-60 and the Prab "Grasshopper."

Following is a brief outline of the most commonly offered robot course, "HT3 Robot Maintenance/Operations." This course is based on Cincinnati Milacron's basic operations and maintenance course (see case study #1), and each trainee is given a CMI operations manual for use during class and on the shop floor once the class is over. As taught by the GM instructors, the 40-hour course involves approximately 40 percent hands-on work and 60 percent lecture and demonstration time.

HT3 Robot Maintenance/Operations

The course begins with a discussion of robot safety and an overview of the components: the robot itself, the robot control, and the pump and tank. The trainees then learn how to start up and shut down the robot (their first hands-on exercise) and proceed to study the mechanical design, the hydraulic circuit, the principal components of the robot, the control, and the hydraulic panel.

During the first 3 days of class the students learn about the robot's motions, how robots interface with peripheral devices, how specific axes are controlled, electrical specifications, the control modules in the main control panel, servo loop theory (how each axis is controlled), board addressing (how information is sent from the computer to specific "addresses," each the home of a particular circuit board). They also learn how to use the teach pendant to program the robot through specific motions and how to make and load the cassette tapes containing the robot's programming instructions.

By the fourth day most students have enough information and have developed adequate skills to enable them to work on the robot, making gain-and-balance and dither adjustments on its axes.* They learn to use oscilloscopes to set PAU's (positional analog units, which provide reference-settings for the operations of each of the robot's six axes).

Homework on the fourth night consists of reading through a complex troubleshooting flow chart, and the fifth day's activities reinforce the previous training by presenting the students with a series of diagnostics and troubleshooting problems to solve on the trainer robot. The instructor is on hand to aid the students in solving these problems, but most students are able to complete these exercises without the trainer's assistance.

Instructors attempt to simulate problems encountered on the production robots, but emphasize that only experience on the floor will create a truly skilled technician able to handle the majority of problems that occur in day-to-day operations.

* See glossary.

Programmable Controllers

The "S" truck plant uses three models of Allen Bradley programmable controllers: the PLC-1, PLC-2, and the Mini-PLC. While the original intention was to give separate courses in these systems on the basic, intermediate, and advanced levels, the trainers found through experience that the systems are similar enough in operation that one course covering all three serves the needs of the plant's maintenance electricians. PLC classes last for 4 days and are approximately 30 percent hands on, 70 percent lecture.

PLC-1, PLC-2, Mini-PLC

After an introductory segment covering the basic concepts of PLC systems (input, memory, and output) and the mechanical components of the Allen Bradley system, the instructor leads the class through an in-depth study of the PLC's memory organization structure and shows them what part of the memory to use for output, the timer and the counter; how to use 16-bit words; and how to "address" the various PLC's in use in the plant*.

The subsequent sections of the course are covered in small segments: 15 minutes of theory, a 5-minute quiz, followed by 30 minutes or more of hands-on application. In this way, students gain knowledge and practical skills in manipulating output, timers, counters, gets, puts, arithmetic functions, and data.* As in the robotics courses, maintenance and troubleshooting skills are developed and reinforced throughout the course.

Evaluation, Certification, and Follow-Up

Although students take frequent quizzes and perform numerous hands-on demonstrations of their skills, no grades are given and all students receive diplomas for attending the courses. (This is partially because, given the small class sizes, instructors easily spot students having problems and give them extra assistance.)

* See glossary for definition of terms.

Follow-up is similarly individualized and informal. Since the training area is adjacent to the shop floor, instructors have made a practice of observing the trainees once they are back on the job and talking to their supervisors about their progress and problems. In addition, instructors are available to help the training graduates with maintenance and troubleshooting problems encountered on the job and to provide capsule refresher courses to those who need them.

While evaluation and follow-up of students are informal, the students fill out formal evaluation forms on the instructors and the courses. These evaluations are used by the trainers to modify old courses and create new ones in response to the students' comments. Some examples of course modifications include the addition of 8 hours to the Cincinnati Milacron course to provide more time for troubleshooting and programming; more emphasis on alignments and adjustments; and a great deal more time on the use and functions of the oscilloscope (a critical testing tool with which many trained electrician are unfamiliar).^{*} The instructors are now developing a free standing, 6- to 8-hour course on the use of the oscilloscope. Other sections of the Cincinnati course were condensed or removed in response to student evaluations: the electrical prints section was shortened since most of it was redundant for the electrician/trainees; and the tooling section, which did not apply to "B" plant applications, was omitted.

The Allen Bradley course was also changed to include a 4-hour session on tape loading and more hands-on time for programming and troubleshooting.

Results

By October 1982, a total of 900 had completed the robot and PLC classes. However, since the figures are based on class enrollments, the precise number of trainees who have completed the courses is unknown. (Many workers have taken two, three, and sometimes as many as six classes). Because of interplant transfer and workers exercising shift preference and bump-in rights (see p. 4), there is a constant turnover in maintenance personnel and a consequent need to provide robotics and PLC training on a continuous basis.

^{*} It should be noted that Cincinnati Milacron, in the last 2 years, has added more hands-on time to its own customer course.

As of August 1982, the plant had lost 46 percent of the maintenance workers trained on the HTJ, 66 percent of those trained on the ASEA, and 42 percent trained on the Allen Bradley PLCs. The vast majority of these workers were transferred to other GM plants.

Problems and Solutions

The "S" truck plant trainers report that they rarely encounter the problem of trainee anxiety cited by a number of robot producers who deliver customer training courses. According to the GM trainers, the probable reason for this is that, in contrast to the occupational variety that can exist in a customer class (mechanics, welders, weavers*, etc.), most of the students in the "S" truck classes have been maintenance electricians whose basic skills and knowledge give them adequate preparation to succeed in robotics skill training. Nevertheless, the GM trainers report that students beginning their classes do require periodic reassurance that they will be able to grasp robotics--which, although made up of disciplines familiar to them, is often a new concept to them in its totality.

The following problems and their solutions were cited by the GM trainers at the "S" truck plant:

- 1) The plant uses some equipment (heat exchangers, for example) in such small quantities that it is inefficient to develop in-plant training for the one or two workers in charge of their maintenance. When such equipment is installed, the trainers either obtain a packaged training program from the vendors or send the workers to customer training classes. Problems do arise when the workers assigned to these machines leave the plant. Since it is difficult to arrange for customer training at short notice, the solution arrived at by the GM trainers is to keep a library of training films made by the vendors.**

* Welding equipment and maintenance repair personnel.

** Since the plant does not project an increase in its needs for such equipment, vendor training (when possible) and training films are likely to remain the most reasonable solution.

2) Since it is unrealistic for the trainers to attempt to cover in 1 week all equipment problems that may occur on the floor, workers who have completed the training programs often encounter unusual problems not covered in the training courses. In such instances the trainers, supervisors, and other more experienced maintenance workers are available to help solve problems. Temporary duties away from the robots or PLCs or a long period of smooth operation may result in trainees forgetting some of what they have learned in class. Informal refresher training on the shop floor helps ease this difficulty, and, when necessary, workers repeat classes they had taken in the past to refresh their knowledge.

3) Another problem experienced by the training staff is their inability to schedule classes for all maintenance personnel who want to receive training in robotics. The addition of a third trainer may help to solve this problem, but the training group does not anticipate having the capacity to accommodate all non-electrician maintenance personnel who express interest in robotics training.

4) The most pressing problem arises from the plant's frequent turnover in personnel (see pp. 13-14). This problem was anticipated from the outset of the training effort and was one of the most convincing reasons for the implementation of ongoing, in-plant training. The training staff has the capacity to set up classes on short notice, and a new maintenance worker is seldom on the floor for more than a week before attending either a robot or PLC course. The training staff believes that, although the Pontiac plant suffers a loss by investing time and money in a worker who leaves for another plant, the division as a whole gains by having an increased number of trained workers.

Benefits of Training

The training staff and the plant management believe that the benefits of the new technology training far outweigh its expense and the problems incurred. The most graphic illustration of how the plant has benefitted from the training is in the robot maintenance statistics for the first 2 years of "S" truck production. When the robots were first installed, they were inoperational 5 to 6 percent of the production time because of equipment

problems. After 3 months, the downtime on the robots had been reduced to 0.5 percent and later decreased even further to 0.3 percent. Now, because of mechanical wear after 2 years of operation, the downtime is up to 0.7 percent--but anything under 1 percent is normally considered a mark of an efficient operation. The superintendent of maintenance, a certified robotics engineer, estimates that the equipment could have had upwards of 20 percent downtime had the maintenance electricians not received adequate training.

Side benefits from the training are many. The chief of these, according to the maintenance superintendent, is the applications laboratory. Another benefit is increased worker satisfaction. The training staff reports a definite rise in worker enthusiasm since the training commenced, and maintenance supervisors state that the hourly maintenance electricians have come up with a number of ways to improve production techniques. A number of trainees were encouraged by the training they received in the plant to pursue more education in robotics or programmable controls in college courses or through reading on their own time. Others come to the training lab during lunch or after hours to work on application problems or to get further instruction. Another intangible but significant result of the training is that, because it provides a common topic of interest, it tends to diminish distinctions between maintenance workers with advanced technical skills and those with less sophisticated skills. The training staff points out that the selection of some maintenance electricians over others to receive training would have had the opposite effect and that the decision to train the entire electrical staff has increased the feeling of homogeneity in the department.

Yet another side benefit of the New Technology Training Program was a 1-week course for applications engineers from other Truck and Bus plants and other GM divisions. The Pontiac Plant Manager is a member of the Corporate Robotics Council. The Maintenance Superintendent has worked on several of the robotics council task forces on training, safety, and applications to develop in-house training courses to meet the needs of the Corporation as a whole. Because of their previous experience in operating in-house robotics training programs, the job of designing and implementing the pilot program was given to the Pontiac "S" truck plant representatives. The pilot program, delivered at the "S" truck plant in June 1981, was designed to provide basic knowledge and some practical experience to the applications engineers who would be responsible

for installing robots in their own plants and coordinating appropriate training for hourly workers. The week-long course included lectures and demonstrations on robot safety requirements; programming experience; lectures by experts on specific applications and methods of installation; lectures on how to work with vendors and how to do cost analyses; and hands-on simulation and interfacing exercises. The "S" plant team delivered the course a second time 3 weeks after the pilot program, training a total of 60 engineers from various GM divisions in the two courses. The course is now offered to GM applications engineers on a regular basis by GMI (formerly General Motors Institute, now an independent technical institute).

EVALUATION OF PRESENT AND FUTURE TRAINING CAPACITY

The New Technology Training Program is, in the words of the editor of Robotics Today (June 1982), "something of a model training program within the corporation." Engineers, managers, trainers, and technicians from numerous GM divisions have toured the plant and visited the training classes, and some have modeled all or part of their own training on the "S" plant's program. Evaluated with respect to its own stated goal--to provide the maintenance staff with the skills to service and repair the computer-aided equipment with maximum efficiency--the program has achieved a remarkable degree of success. The low downtime on the equipment (0.3-0.7 percent), the training staff's ability to offer regular training and to train on short notice when necessary, the staff's responsiveness to student evaluations, and its ability to generate new courses all testify to the program's success in meeting its goal. The maintenance department, which views training as integral to the service it supplies to the production departments of the plant, is working to increase its service (and training) capacity by increasing its training equipment holdings--a new hydraulic training console has just been purchased, for example. In addition, the head trainer is currently setting up a circuit board repair room, which will enable the department to repair its own boards instead of returning them to the vendors and which will also involve further training for the electrician who will work in the repair room on a rotating basis.

A survey commissioned by OTA of industries that use and produce computer-aided manufacturing equipment reveals that the most frequent obstacle cited by users or potential users of such equipment to setting up training programs for their

workers was "inadequate benefits relative to costs." The "S" truck plant management found the contrary to be true. (It should be noted, however, that most of the user companies surveyed had fewer capital, technical, and human resources with which to implement training than the GM plant and had fewer installations of CAM equipment.) The "S" truck plant's maintenance superintendent states that there is a direct correlation between the efficient operation of the plant and the provision of adequate training to its maintenance workers. And the head trainer points out that, once the initial implementation and equipment costs have been absorbed, there is a dramatic savings in training costs and production time when new workers can be trained in the plant on a schedule timed to the plant's production schedule--as opposed to training provided by vendors, which is both expensive and difficult to schedule. The head trainer, in fact, believes that the plant can no longer afford to be without in-house training for maintenance workers.

Since the training was instituted at the start of "S" truck production, the effects of training on production cannot be measured on a "before and after" basis.* It may be assumed, however, since the plant management determined that the skills training provided in the "G" van production (management training, apprenticeship training, and training delivered by equipment vendors) was not adequate to the new skills needs occasioned by the installation of the CAM equipment, that the demands of the new technology required a new method and a new structure of in-plant training. The training group has been considering adopting some computer-aided training techniques in its new technology training but, to date, their investigations have only reinforced their feeling that the personal contact and practical assistance that can be provided by an instructor working with a small group of trainees are more productive than computer-aided learning, at least in its present state of application.

* According to GM engineers, the complex nature of "launch" efforts (i.e., beginning production on a new line of vehicles)--involving numerous items of production equipment, transportation of parts and materials, scrappage, and a vast array of other factors that must be coordinated--makes it extremely difficult to compare one launch to another. Not only do the varying circumstances and requirements of different plants make plant-to-plant comparison difficult, but this difficulty remains when attempting to compare one launch effort to another within a single plant, since production procedures and requirements will differ from one line of vehicles to another.

Trainee Evaluation

The 4 maintenance electricians interviewed reported that the training they received in robotics and programmable controller courses was well delivered and absolutely necessary to them in the performance of their maintenance duties on the floor; all, however, agreed with the trainers' statement that the real learning experience occurs on the floor after the training has been completed. One past trainee, who had taken a robotics course but who had not had the opportunity to work with the robots to any great extent, felt that he would need a refresher course if he were assigned to work with robots on a full-time basis. This, too, confirms the trainers' statement that, as with other types of machine-skill training, constant day-to-day contact with the equipment is necessary to maintain and hone the skills learned in class.

Most of the workers interviewed stressed the importance of the safety segments of the classes--both to avoid personal injury and to prevent damaging expensive equipment. All felt that the hands-on segments of the courses, especially the troubleshooting, were the most helpful, and most felt that in-plant training delivered by plant personnel created a more relaxed atmosphere than training delivered by vendors. One of the electricians interviewed said that parts of the robot course were "too technical" because, at the time he took the training, he was "too green"; he felt that a formal refresher course would be appropriate and perhaps even more useful than the original one now that he is more familiar with the equipment. Another robotics graduate stated that refresher courses should be designed as workshops or seminars, which would allow electricians who have had experience working on robots to discuss common problems, to present practical solutions to unusual problems they had come across, and to increase the general pool of practical knowledge by discussing individual experiences.* All of those interviewed welcomed the opportunity to receive training in computer-aided equipment (one said, "the more training the better;" another said that it was more interesting to work on CAM equipment; and another said that he liked working in technical areas, but would have felt "overwhelmed" without proper skills training and good

* Although a number of workers have taken the regularly scheduled courses a second time to refresh their knowledge, there is, at present, no course that is formally structured as a refresher course.

manuals and guidebooks to use on the floor). Some expressed an interest in taking college courses in robotics on their own time, and some said that the training not only served their current work-related needs in the plant, but also gave them the skills and the confidence to face the possibility of having to look for another job in case of future lay-offs.

Union Evaluation

G.M.'s contract with the U.A.W. specifies that the union and the company work together to develop new technology training and that—when possible—such training should be operated in-house. The president of UAW Local 594 said that, from the local's point of view, the training has "gone smoothly," that the union members are "well satisfied," and that no problems with the training have been identified to date.

Future Capacity

The "S" Plant Maintenance Department has demonstrated its ability to identify employees with the potential to be trainers, to train them to be instructors, and to implement on-going training on a departmental scale. It should be emphasized here that the type of training provided by the New Technology Training Program—i.e., on-going, structured classroom training of skilled tradespeople in a laboratory environment allowing opportunity for hands-on practice and application—is not only a new departure for the "S" Truck/"G" Van plant but also for the vast majority of plants within the General Motors Corporation. Although formal classroom training has been delivered to managerial, supervisory, and technical personnel for "decades," according to a representative from the Corporate Education and Training Department, classroom training for skilled tradespeople is relatively new.

In-Plant Training for Skilled Tradespeople: A New Focus

Until just a few years ago, auto workers who had achieved journeyman status were considered to be "trained workers" and therefore received little job-specific training other than "launch-training" (training in skills required to operate new equipment installed for the "launching" of a new line of vehicles). For the most part, launch-training for skilled tradespeople was delivered by foremen or equipment vendors directly on the shop floor, and the

equipment used for training was production equipment, which placed a severe limitation on its availability for training purposes. While this procedure was considered to be adequate for the less sophisticated equipment used in "hard" automation lines, it became increasingly clear to many division and plant managers and the Corporate Education and Training Department that training in the use and maintenance of computer-aided equipment required a new approach. The training and development laboratory in the Pontiac "S" Truck plant was one of the first full-time training labs in the corporation. Now, the Corporate Education and Training (E & T) Department is encouraging other plants to establish technical training facilities incorporating training laboratories and a representative of the Corporate E & T Department predicts that most GM plants will do so in the coming years.*

The concept of the training laboratory is significant for two reasons: first, it requires that plants set aside equipment dedicated to training and application research; second, it supports another concept that is relatively new to GM--the provision of year-round training for skilled tradespeople. GM training representatives on both the plant and the corporate level agree with the growing number of educators, industrial training representatives, and trade union representatives that "lifelong learning"--the continuous updating of skills and knowledge to keep pace with technological advances--is a necessity for skilled tradespeople as well as scientists, engineers, and technicians. The establishment of training laboratories that give plants the capability of holding ongoing technical training classes for hourly personnel is one way of meeting this need. In-plant classroom and laboratory training for skilled tradespeople--once the exception, rather than the rule--will, according to the Corporate Education and Training Department, become the norm as more and more plants install sophisticated equipment.

Reinforcing the Fundamental Skills of the Trade

Another corporate-wide need brought to light by the growing recognition of the need for specialized training on robots and other reprogrammable equipment is the necessity of reinforcing the core trade skills of hourly workers. Corporate Education and Training personnel, who have the responsibility of

* This will be an evolutionary process, occurring gradually over the course of time.

providing technical assistance and professional training advice to individual plants, discovered that a major obstacle to "high technology" training is that a significant number of journeymen had lost some of the fundamental skills of their trades--basics which form the foundation for the advanced skills training necessitated by the installation of reprogrammable equipment.* This problem has received a great deal of attention in recent years and a number of refresher courses and/or courses that include basic skills training as preparation for advanced training have been delivered in a number of GM plants.

Progress and Problems

The "S" Truck plant's new technology training program has been of value to the division and to the corporation as a whole by serving as one of the models of the year-round training lab concept, by providing advice to other plants with newly installed programmable equipment, and by aiding the corporation in such corporate-wide training efforts as the robotics training for applications engineers now in operation at GM. The New Technology Training Program has been successful in serving the needs of the S-Truck Assembly Plant to maintain the new sophisticated equipment by upgrading the skills of the employees that service the equipment. As the need for additional new technology training is required, programs will be developed to implement those requirements. Another benefit of the program is the Maintenance Department's ability to coordinate training schedules with the ongoing responsibilities of the department and to make sure that the training corresponds to the workers' individual responsibilities. Formal technical training departments organized to serve the entire plant workforce have been discussed for some time at various GM plants, but GM representatives believe that such formal plant-wide mechanisms would not serve the same purpose as training located in the department it serves. Training delivered by a centralized training department is, according to GM, more generalized and broader in scope than the type of training

* One root cause of this loss of core skills is, according to GM training representatives, the late adoption by the American auto industry of high technology equipment and methods. During the fifties and sixties, when most of today's journeymen were trained, the level of automation was such that many journeymen, lacking a challenging opportunity to use their skills, suffered skill atrophy.

delivered in the "S" Truck plant New Technology Training Program. Programs on the "S" Truck model, they believe, best meet the specific needs required for servicing and operating high technology equipment.

While there are no immediate plans to increase the level of programmable automation in the "S" Truck plant, it is not inconceivable that the pressure to compete with Japanese and European automakers and the pressure to increase quality and productivity will motivate the plant's management to install computer-aided equipment in areas of the plant that are currently unaffected by reprogrammable automation. Should this situation arise, plant management will not only be faced by the need to extend "high tech" training to other areas of the plant, but may also be faced with worker-displacement. Both GM and Ford are addressing the problem of retraining already laid-off workers under separate retraining plans, each operated jointly with the United Auto Workers. The UAW's approach to the problem of potential future layoffs is, in part, to work to obtain assurances in collective bargaining agreements that workers whose jobs are replaced by automated equipment be trained in the operation of that equipment. (The UAW reports that there have been numerous instances of assembly line workers, for example, being trained to change programs and tools on robots introduced on assembly lines.) Such work, however, may become less challenging than the assembly line work it replaces.

GM "S" plant and corporate representatives have provided the following responses to questions concerning potential displacement and/or retraining problems for currently employed workers whose functions may be replaced by programmable automation:

- 1) What is planned in the Pontiac "S" Truck plant with respect to programmable automation over the next 5 years?

The management at the "S" truck plant is currently conducting feasibility and cost studies on further applications of programmable automation. There are no firm plans in place at this time.

- 2) Is there a corporate-wide strategy to retrain workers before they are laid-off, either for new positions within GM or for non-GM jobs? How can the corporation identify those plants facing shut-down or significant

decrease in work force soon enough to address the retraining problem before workers are laid off?

GM is constantly training employees to meet the future requirements of the auto industry. Extensive training will occur for laid off employees being recalled to the three new assembly plants currently under construction. Where possible, management in GM is taking steps to train and retrain existing and laid off workers for future job opportunities.

- 3) How does the corporation view its responsibility regarding hourly workers to be displaced by programmable automation? How does the management of the "S" Truck plant view that responsibility?

GM is highly concerned about its employees and the continuance of employment opportunities. The direct effects of programmable automation on employment is believed to be minimal. Without the installation of such technology and the increased efficiency provided by it, our competition would overtake us.

- 4) How many workers were displaced when "G" Van production stopped? How many of those workers were recalled to work on the "S" Truck?

We have no clear-cut way of comparing the production process of the G-van to the production process of the S-truck. Production of the G-van is much more complex than the S-truck and requires more parts and more people to build.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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Part C - Individual Education and Training Case Studies

- C.1-- CINCINNATI MILACRON INDUSTRIES, INC.
- C.2-- GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI: "NEW TECHNOLOGY TRAINING"
- C.3-- BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS
- C.4-- CAD/CAM OPERATOR TRAINING PROGRAM, GLENDALE, CALIFORNIA
- C.5-- MANUFACTURING ENGINEERING APPLICATIONS CENTER, WORCESTER, MA
- C.6-- NEW ENGLAND PROGRAMMABLE AUTOMATION CUSTOMER TRAINING: COMPUTERVISION, GCA, AUTOMATIX
- C.7-- OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS: ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS
- C.8-- UNIVERSITY OF MICHIGAN
- C.9-- CADAM, INC.: CUSTOMER TRAINING IN COMPUTER-AIDED DESIGN
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- C.11-- WESTINGHOUSE DEFENSE AND ELECTRONICS SYSTEMS CENTER, BALTIMORE, MD
- C.12-- TEXAS INSTRUMENTS
- C.13-- PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.3— Brigham Young University: The Education of
Technologists**

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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MAY 1984

FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

BRIGHAM YOUNG UNIVERSITY
THE EDUCATION OF TECHNOLOGISTS

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BRIGHAM YOUNG UNIVERSITY:
THE EDUCATION OF TECHNOLOGISTS

I. SUMMARY/BACKGROUND

Introduction: Engineering Technology

In 1967, Brigham Young University (BYU) became the first educational institution in the country to receive accreditation from the Engineers Council for Professional Development (now known as the Accreditation Board for Engineering and Technology, or ABET) for its baccalaureate programs in manufacturing engineering technology and design engineering technology. In 1971, BYU's B.S. program in electronics engineering technology was also accredited by ABET.

While engineering technology is closely related to engineering--and while the education of engineers and technologists overlaps in many areas--there are significant differences between the two disciplines. BYU's College of Engineering and Technology offers the following definitions which clarify the distinction between the two:

Engineering is the profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize economically the materials and forces of nature for the benefit of mankind. Technology is that part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it occupies a position on the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.*

Technologists, in essence, are applied engineers. This may at first seem to be a misnomer, since engineering is traditionally considered to be an applied discipline. However, a brief overview of developments in engineering education in the United States over the past 25 years clarifies the issue. When the U. S. space program began in the late fifties and early sixties,

* Brochure, College of Engineering and Technology, p. 2.

engineering schools began responding to the increased need for science-oriented courses by adding advanced courses in mathematics, physics, and chemistry to their curricula. In the process, traditional engineering laboratory courses in drafting, machining, and processing were dropped out of the curricula to make room for the more theoretical courses required to meet the needs of sophisticated space-age technology. As technical knowledge and applications multiplied, the gap spread between engineers, whose education was becoming increasingly theoretical, and technicians engaged in manufacturing and design occupations. Baccalaureate technology programs (some began as 2-year technician programs, while others were originally designed as 4-year programs) were created to bridge the occupational gap between the engineer and the technician. According to BYU representatives, it is no longer possible for one person to master the skills and knowledge required to cover the spectrum from conceptualization to the manufacture of a final product. Now, the idea for a product often originates with marketing, engineering, or management; the engineers and technologists work as a team to develop the layout and detailed design and to test the prototype product. The technologist and engineer work together plan, design, and test the machines or procedures for building a system or its components, and then the craftsmen and machine operators bring about the actual production.* In terms of theoretical orientation, the progression goes from abstract at the design research engineer's end, to highly practical at the technician's and craftsman's end. While the engineer, then, may be interested in why a system, product, or procedure performs so he/she can create plans or designs, the technologist is concerned with how that system, product, or procedure performs so that the engineering plans can be applied in practice and are implemented in the most productive manner.

* The Accreditation Board for Engineering and Technology (ABET) also recognizes the necessity of engineers and technologists working together as a team in industrial projects. According to ABET representatives, it is for this reason that over 700 associate and bachelor level technology programs have been accredited since the 1960's. (See Appendix A for a general discussion of the growth and need for engineering technology education--based on a report by the American Society for Engineering Education.)

Engineering Technology Programs at BYU

BYU's Technology Department has gained national prominence, especially among industrial employers, many of whom say that the technology graduates have precisely those skills most in demand by firms implementing computer-aided manufacturing, design, and applied electronics procedures. Created with industrial needs in mind, the technology programs at BYU were quick to incorporate computer-aided techniques and machinery. In the early seventies, individual faculty members in the manufacturing and design programs began exploring ways of acquiring computer-aided equipment to enable them to integrate CAD and CAM into the undergraduate curricula and initiated a number of research projects. In addition, data communications and real-time computer control were developed. One of these used group technology classifications* to create what has now evolved into DCLASS—a computer program that classifies, organizes, and retrieves information to assist in process planning, material selection, circuit design, generation of time standards, and other industrial applications. DCLASS (described in greater detail on p. 34) is now licensed by 20 companies for use in 30 plants, and revenues received from the sale of DCLASS licenses help to support continuing research into computer-aided manufacturing by BYU faculty and students. In 1977, the Technology Department instituted a master of science degree program in computer-aided manufacturing; the program has expanded over the years to encompass computer-aided design and computer-aided electronics testing and is now known as the Computer Integrated Manufacturing Program. The Masters program and the undergraduate programs in manufacturing engineering technology and design engineering technology are the primary subjects of this study.**

To present a complete and accurate picture of the Technology Department's programs, it has been necessary to omit information on the activities of other departments at the university. It should be noted, however, that in recent

* See glossary.

** The Electronics Technology program currently lags behind the other two technology programs in incorporating computer-aided techniques. This parallels the relative lag of industry in computer-aided electronics testing. This program will therefore receive less attention in the present study. A brief overview of the Electronics Engineering Technology Program is contained in Appendix 3.

years, the traditional engineering departments have been building the capacity in what they refer to as computer-assisted engineering* and have joined with the Technology Department to form the Computer Assisted Design, Engineering, and Manufacturing (CAEDM) Committee to coordinate the use of computers within the College of Engineering and Technology and to increase communication and cooperation between departments.

The remainder of Section I of this study provides general information on the University and the Engineering College. Section II is devoted to the education and research conducted within the Technology Department. Section III summarizes the Technology Department's industrial affiliations, and Section IV contains an evaluation of the Technology Department's capacity to meet present and future training and educational needs and discusses CAEDM's role in coordinating the activities of all the departments in the engineering college.

Brigham Young University: General Background

Brigham Young University--with a main campus in Provo, Utah, and a campus in Hawaii--is the largest private university in the United States. Founded in 1875 as the Brigham Young Academy, an elementary school with 29 students, BYU currently has an enrollment of approximately 28,000 at its Provo campus and over 1,800 in Hawaii. Approximately 98 percent of the students are members of The Church of Jesus Christ of Latter-Day Saints (also referred to as the LDS Church), which supports the University financially and guides the education of

* Computer-Assisted Engineering (CAE) is defined by BYU engineering faculty as "the application of computers to the whole range of calculation and simulation tasks needed for modern professional engineering," including finite element analysis and routines for optimization, linkage synthesis graphics*, and numerical utility*. (+ See glossary for definition of terms.)

its students.* While its primary intent is to provide undergraduate education, BYU does maintain a number of graduate programs on the master's and doctoral levels which have a combined graduate enrollment of 2,890. The student body is approximately equally divided between men and women; and, in terms of geographical origin, approximately 35 percent of the students are residents of Utah; just over 60 percent are residents of other states; and around 5 percent are citizens of other countries.

The geographical make-up of its student body reflects the University's orientation and the increasingly international membership of the LDS Church. Adding to the international atmosphere are the returned missionaries--students who, usually in their sophomore year, are sent by the Church on ecclesiastical recruiting missions to one of 108 countries. Forty-four percent of the current students are returned missionaries. Their missionary experience provides them with linguistic skills and exposure to other cultures and also--according to BYU faculty and employers of BYU graduates--gives them additional maturity which helps them to apply themselves more intently to their last 3 years of university work and enhances their on-the-job performance after graduation.

* Over 70 percent of the University's total expenses are covered by the tithes of the LDS Church. Therefore, according to the University catalog, "students and families of students who are tithe-paying members of the Church have already made a significant contribution to the operation of the University. Because non-Mormons will not have made this contribution, they are charged a higher tuition, a practice similar in principle to that of State universities charging higher tuition to nonresidents." Because of the financial support provided by the Church, tuition is low, even compared to public educational institutions: undergraduate fees are \$610 per semester for LDS students and \$915 for non-LDS students. The doctrine of the LDS Church affects the educational policies and philosophy in a variety of ways. Admission requirements, for example, include personal behavior which "conforms to the standards of The Church of Jesus Christ of Latter-Day Saints. High standards of honor, integrity, and morality; graciousness in personal behavior; application of Christian ideals in everyday living; and abstinence from tobacco, alcohol, and harmful drugs are required of every student" (University Catalog, p. 11). Religious instruction is one of the University's major goals, and University requirements include 14 semester-hours of religion courses (approximately one two hour course per semester).

The College of Engineering and Technology

The combination of the campus' geographical isolation--Provo sits at the foot of the Wasatch Mountains, 45 miles south of Salt Lake City--and the national and international make-up of its student body has a tangible effect on the outlook and external relationships of the University's professional schools, such as the College of Engineering and Technology. While the Engineering College does work with some high technology firms within the local area, the majority of the industrial affiliations formed by the college are with firms from outside the state. Furthermore, most of the graduates of the college are employed by firms and agencies outside of Utah, and students who take advantage of the college's cooperative education program usually relocate temporarily to complete their work experience.

The College of Engineering and Technology has a total enrollment of approximately 3,400 students working on undergraduate and graduate degrees in six departments: Chemical Engineering, Civil Engineering, Electrical Engineering, Mechanical Engineering, Industrial Education, and Technology. The four engineering departments offer traditionally structured undergraduate engineering programs and masters- and Ph.D.-level graduate degrees. The Industrial Education Department offers a 2-year associate degree in light building construction; five baccalaureate degree programs which prepare students to teach industrial arts and technical education in secondary schools and colleges or to enter building construction, physical plant administration, or industrial management fields; and four masters degree programs that prepare students for management and training positions in industry and education. The Technology Department offers three programs leading to the baccalaureate degree (Manufacturing Engineering Technology, Design Engineering Technology, and Electronics Engineering Technology), and a master's program in Computer-Integrated Manufacturing with program options in computer-aided manufacturing (CAM) and computer-aided design (CAD), and elective courses in computer-aided testing (CAT). In the Fall semester of 1983, the Technology Department will also offer a graduate program leading to the degree of Master of Technology Management.

II. ENGINEERING TECHNOLOGY: EDUCATION AND RESEARCH ACTIVITIES

A common misperception by outside observers—including a number of BYU faculty and students outside the Technology Department—is that the department offers undergraduate programs in computer-aided design and manufacturing. Actually, however, while computer-aided methodologies and techniques are incorporated into the curricula of the three technology programs whenever appropriate, the programs themselves focus on providing students with a strong foundation in the basics of the three disciplines—design, manufacturing, and electronics—augmented by computer techniques currently in use in industry. It is at the master's level that the technology programs focus solidly on computer-aided manufacturing and design.

The incorporation of computer-aided techniques and coursework into the undergraduate curricula varies from program to program—reflecting 1) current industrial practices in the three disciplines, 2) the varying amount of conventional manufacturing and design skills required by the different disciplines, and 3) the availability of industrial equipment. Thus, the design curriculum is most suffused with computer-aided techniques and applications both because of the large amount of CAD equipment in the department and because of the rapid spread of computer-aided design in industrial settings. The manufacturing program, while it is provided with well-equipped labs, stresses conventional manufacturing techniques for the first 3 years of study to provide the foundation for the advanced computer-aided manufacturing techniques and applications taught in senior and graduate-level classes. The electronics program is the least involved in computer-aided applications—a reflection of the relatively late development of computer-aided testing (CAT) technology and difficulty in obtaining CAT and process instrumentation equipment.

While each technology curriculum includes required and elective coursework in the other two curricula, the education of manufacturing, design, and electronics technologists differs significantly. For this reason, this section of the study will first discuss the common features of technology education at BYU and will then describe the manufacturing and design programs separately. Following the descriptions of the undergraduate manufacturing and design programs is a discussion of the graduate-level program in computer-aided manufacturing, which developed as a natural outgrowth of the increasing emphasis on computer-aided techniques in the undergraduate programs.

Undergraduate Programs: Common Features

Goals

The particular goals and objectives of individual programs are discussed in the program descriptions. The Technology Department as a whole, however, has identified a number of goals which have a significant general impact on the curricula and instruction in all of the programs. A major departmental goal is to retain its now-recognized position in the forefront of engineering technology programs. In support of this, the faculty attempts to ensure that each course builds on the skills and knowledge taught in previous courses and that new industrial methods and equipment are incorporated as soon as possible. (For example, students who learn the use and function of computer-aided design terminals in their sophomore or junior years are given the opportunity to make use of those skills in succeeding courses.)* The faculty—together with faculty in other departments in the University—is also attempting to refine and improve instructional delivery methods, aided by research into computer-aided instructional techniques (see p. 51). Other general goals are to "educate the 'whole person'" by requiring students to take a broad variety of general education courses and to instill in the students a recognition of the necessity of "life-long learning."** While life-long learning is, in the most basic sense, the responsibility of the individual, the graduate who stops learning rapidly becomes obsolete when he or she leaves school and enters a technical field. For this reason, the Technology faculty places major emphasis on bolstering the students'

* While this may seem to be a self-evident precept of educational programming, it is often difficult to achieve. Engineering faculty and students in other universities, for example, have noted that courses involving student use of computers are so widely spaced in the curriculum that students lose some computer skills before they are able to reapply them in later courses.

** "Life-long learning" and "life-long education" are terms employed by a large number of educators, training specialists, and industry representatives to emphasize what they see as the necessity for those in technical fields to engage in formal and informal continuing education in order to meet the "practitioner" requirements of changing technologies. (See American Society for Engineering Education, "Engineering and Engineering Technology Education, A Reassessment," May 1977, p. 7.)

commitments to learn how to learn on their own; to keep themselves apprised of new developments in their professional fields; and to continually update their skills and knowledge.

Faculty

Two distinguishing features mark the members of the Technology faculty. First, all have had significant industrial experience in their instructional fields. That experience ranges from a minimum of 3 to 5 years in industry to a maximum of 10 or more years. Second, while industrial experience is required of the faculty, doctoral degrees are not required. Of the 16 full-time faculty members, 6 have doctoral degrees and the remainder have masters' degrees in technology or engineering. Although the department actively encourages its faculty to engage in research and to publish the results, that research is often of a practical and applications-oriented nature.

Teaching Methods and Materials

All of the technology programs emphasize practical experimentation and application of the theoretical material taught in the classroom. The programs require approximately 50 percent of the students' time to be spent in laboratory work. Comments by both students and faculty, however, indicate that many students spend more than the required amount of time in the laboratories, so that the ratio of lab work to class work may actually be higher than one-to-one. Another instructional method in the department is the assignment of actual industrial projects to undergraduate students. Instructors on the design faculty, for example, are frequently requested to use the school's CAD equipment to perform benchmark studies* of company drawings to help them determine the efficiency of a CAD system for the company's particular purposes. The studies themselves are assigned as projects to upper-division design students, who thereby gain actual industrial experience. Other advanced students participate in similarly practical research projects conducted or coordinated by department faculty, a number of which are described on pp. 34-36. Several technology faculty members are now working on computer-aided learning techniques and instructional systems, one

* See glossary.

of which--the Computer Aided Simulation Training System (CAST)--is being developed for use in both industrial and educational manufacturing programs (see p. 35). When the CAST project is completed, the learning package will contain a total of 300 learning modules--each providing instruction on a specific manufacturing process. As these modules are developed, they are incorporated into the manufacturing curricula at BYU.

One problem facing the department is the unavailability of appropriate textbooks in the CAD/CAM and applied electronics areas. Since textbooks on technology quickly become outdated, the department is continually looking for other ways of supplying students with written material. A "Group Technology Collection" has been established in the University library to give students access to the growing number of reports and articles on productivity, manufacturing processes, and new developments in hardware, software, computerized data-bases, and other topics. In addition, copies of monographs discussing current topics in manufacturing and design are reproduced and distributed to students for their personal collections. Another "library" resource, although not textual, is a growing "parts library" containing a collection of manufactured parts, which are used in the classroom to illustrate the end-products of the manufacturing processes being studied.

Facilities and Equipment

The major laboratories and equipment items are discussed in the descriptions of the manufacturing and design programs beginning on p. 13. Even though the present facilities are well-equipped relative to a number of other educational institutions, they are still inadequate to the needs of the growing Technology student-body. This problem will be significantly reduced when the new Technology Building is completed in late 1984. Currently, technology laboratories and classrooms are spread throughout six separate buildings on the campus. The new building, which will occupy 48,000 net square feet and will be largely devoted to laboratory space, will enable the department to consolidate its laboratories, classrooms, and faculty offices.

Enrollment Trends

Enrollment in technology department programs has tripled in the last 3 years. Currently, there are just under 1,000 students enrolled in the three

undergraduate programs: approximately 210 in manufacturing, 220 in electronics, and over 550 in design. This poses a problem for the department and the University in that even the new facility will only be capable of accommodating 900 students. Consequently, a policy of "enrollment control" has been introduced on a University-wide basis. Since enrollments in all of the technology programs are increasing, and the manufacturing and electronics programs are expected to reach enrollments of up to 300 each within the next 5 years, the design program enrollment will be gradually reduced over the coming years. Of the approximately 1,000 students, fewer than 50 are women, and most of those are enrolled in the design program.* More detailed discussion of enrollment trends can be found in the program descriptions beginning on p. 13.

Cooperative Education

The College of Engineering and Technology operates an active cooperative education program which gives students the opportunity to integrate their academic studies with periods of work experience. Some of the traditional engineering departments tend to discourage students from entering the cooperative education (co-op) program by structuring the curriculum into a lock-step sequence which creates difficulties for students who spend time off-campus. The Technology Department, on the other hand, actively encourages its students to take advantage of the co-op program. Approximately 45 percent of the 123 students enrolled in the college's co-op program in 1981-82 were technology students who worked at such firms as Boeing, G.E., General Dynamics, Ford Aerospace, Honeywell, Eaton-Kenway, and Westinghouse. Aside from the obvious advantage of obtaining practical experience to supplement academic knowledge and laboratory skills, a large number of technology students have the additional advantage of discovering through experience whether or not they want to accept the permanent job offers they usually receive from the co-op employers.

* In recent years, BYU has been actively encouraging "equal opportunity and rights for women students." According to the Technology Department chairman, women who graduate from any of the department's programs will have an excellent chance of being hired because of equal employment opportunity programs. While the number of women in the design program is growing, many women drop out of the manufacturing program. Technology department faculty say that this is primarily because a number of women are uncomfortable with manufacturing laboratory work.

Ironically, the success of the co-op program has created a problem for the department in that a number of employers have tried to convince their co-op students to stay on with the firm rather than return to school to complete their degrees. Another problem, which is somewhat limiting to some technology students, is the geographical isolation of the Provo campus and the consequent necessity for over half of the co-op students to relocate temporarily to accept out-of-state employment. Furthermore, a large number of BYU undergraduates are married--many with young families. These students, especially, find it difficult to accept an out-of-state co-op assignment. For these and other reasons--including competition from other schools, the downward trend in the economy (which has caused a number of firms to discontinue their co-op programs), and increasing pressure on the University to turn out graduates--the co-op program has tapered off in recent years from a peak of 235 students in 1979-80 to 123 in 1980-82. Nevertheless, it still receives the support of the college and the active participation of technology students.

Counseling and Career Guidance

The University Counseling Center offers both group and individual counseling for students with personal or academic problems, and the Engineering College Advisement Center provides specific advice on engineering and technology programs. The University also has a Career Educators Program that provides the following services: 1) courses on life planning and decision-making, career exploration, and employment strategies; 2) interest testing; and 3) academic and occupational counseling.

In spite of all of these formal counseling and guidance channels, some technology faculty members feel that a great deal of the students' time and money is wasted because they do not receive comprehensive interest- and ability-testing when they are admitted to the University. This lack is felt most keenly in the Technology Department where a major portion of the undergraduates are transfer students from other colleges and departments. Although some of these students discover the Technology Department through regular counseling channels, the vast majority learn of the department and the content of its curricula almost by accident--through friends, chance conversations, or parties outside the University.

Manufacturing Engineering Technology

Like its sister program in Design Technology, the Manufacturing Technology program was organized in 1960 and accredited by what is now known as ABET in 1967. The program was constructed in such a way that, over the years, it has been able to accommodate the industrial trend toward computer-assisted processes and equipment without significantly altering its original focus. At the same time, the program has been refined over the years to minimize duplication, improve the course sequence, establish meaningful prerequisites, and give students flexibility in choosing areas of concentration.

Both the instructional program and the major research projects of the faculty and students are characterized by a highly systematic approach. That approach relies on the following:

Definition of the subject matter (in this case manufacturing), its essential elements, and the activities involved;

Identification of the need for a program in manufacturing technology and the processes and approaches to be employed to meet that need;

Classification of the processes and components of manufacturing to form the basis of a systematic approach to teaching and research. The notion of classification as employed by the manufacturing faculty rests on the following description: "Classification not only assists the memory by arranging individual items into groups, but also expresses a relationship of things and leads to the discovery of their laws."* BYU's approach is based on an attempt to discover the laws governing manufacturing--including economic laws, laws of physics, metallurgy, control systems, etc.--define them, and teach them to the students.

* Dr. Dell Allen.

BYU bases its manufacturing curriculum on a broad definition which encompasses the total manufacturing enterprise: "the series of interrelated activities and operations that involve product design, planning, producing, materials acquisition and control, quality assurance, management and marketing of discrete consumer and producer goods." Manufacturing activities are classified into nine categories: product design activity, marketing, management, material control, manufacturing engineering, finances and personnel, production, and quality assurance. While the curriculum at BYU focuses primarily on one of those activities--manufacturing engineering--it also attempts to provide a background in the other activities.

To create the manufacturing curriculum, faculty members drew on their own industrial experience, informal industrial contacts, and a number of formal surveys and studies to assess industrial need, opinions of manufacturing educators, and requirements of accreditation agencies. After an exhaustive evaluation of the manufacturing discipline, the faculty found that the major factor distinguishing manufacturing engineers from those in other disciplines is the ability to do manufacturing planning and estimating. That ability, in turn, is built on knowledge of materials and metallurgy, production tooling, quality assurance, production information and control systems, plant layout and material handling, manufacturing systems and management.

The core courses developed to form the basis of the manufacturing technology curriculum are, therefore, those which develop the skills and knowledge required for manufacturing planning and estimating.* These are supplemented by special education courses in economics, mathematics, statistics and computer science, physical science, and electronics and design technology which provide the students with basic knowledge of other manufacturing activities related to their discipline. Also required are general and liberal education courses.

* To further refine the curriculum, the faculty conducted a survey of graduates of 13 manufacturing technology programs, their managers, and educators from the institutions offering the programs. Tabulated results of the survey were then evaluated by seven experts, who also voted on various performance objectives to be maintained in manufacturing curricula. These performance objectives were also incorporated into BYU Manufacturing Technology curricula.

Program Goals and Objectives

The two major goals of the Manufacturing Engineering Technology program are 1) to give the students opportunities for individual development, and 2) to prepare them with the latest knowledge and skills needed to lead or supervise personnel engaged in manufacturing operations, and to help in the development of new products and processes.* To achieve those goals, students are provided with theoretical instruction linked to extensive application experience. The core coursework is planned around eight specific areas of study which correspond to the requirements for manufacturing planning and estimating discussed on the previous page. These eight areas are 1) manufacturing planning, 2) manufacturing processes and materials, 3) manufacturing development, 4) production tool and machine design, 5) production planning and control, 6) plant layout and materials handling, 7) inspection and quality

* See Appendix and Introduction (pp. 1-2) for a review of the industrial activities prepared for by technology education compared to those supported by engineering education. In this regard, however, the following comment by a Bechtel Corporation representative should be noted: "The hard, cold, practical fact is that anyone with any type of engineering education will aspire to be called an engineer, and there is not the nice, clean interface that the educators think there is between the duties of the many people engaged in an engineering-oriented program, be it design, construction, manufacturing, or operations." (Quoted from Engineering Technology Education Study Final Report, p. 51.)

assurance, and 8) manufacturing management. Specific objectives have been developed for each area of study.

Space limitations preclude a full listing of the objectives listed under each area. The objectives for instruction in manufacturing planning, therefore, will serve as an example. Those objectives are as follows:

- o To familiarize the student with the function of discrete component manufacturing systems and the characteristics, analysis, and synthesis of such systems with emphasis on computer-aided manufacturing planning.
- o To aid the student in developing the ability to analyze parts and products for manufacturing feasibility, to plan process operations and sequence, to estimate manufacturing costs, and to select manufacturing tools, machines, and equipment.
- o To explore the various technical aspects of automation and numerical control systems (including labor-management responsibilities); to give students experience in manual and computer-aided numerical control programming; and to give them experience working in local industries to solve manufacturing problems through the use of mechanization and automation.

Computer-aided processes and techniques are incorporated into the coursework when appropriate; it should again be stressed, however, that the undergraduate curriculum emphasizes and builds on conventional manufacturing techniques and processes which serve as a foundation for the study of computer-aided manufacturing.

Faculty.

Six permanent faculty members are on the Manufacturing Technology staff. One holds a Ph. D., one an Ed. D., one is completing his Ph.D., and the others have Masters of Science degrees. All have a number of years of industrial experience, and most are actively engaged in industrial consultation and in industrially oriented research. One senior faculty member, who took a major

role in developing the manufacturing curriculum, also developed the DCLASS software package and is now coordinating the development and production of industrial training packages sponsored by a consortium of 13 industrial organizations and educational institutions (see pp. 32-34).

Facilities and Equipment

The Manufacturing Technology laboratories are distributed through four buildings on the campus. The laboratories--some of which are shared with the Mechanical Engineering and Industrial Education Departments--occupy over 15,000 square feet (total) and include facilities for machine tool operations, fluid power experiments, casting processes, metal forming, metallurgy, quality assurance, materials science, welding, metal forming, and advanced welding. Also available is a CAD/CAM computer area and a large machine-tool-performance and CAM lab.

A comprehensive listing of the conventional and computer-aided equipment available to Manufacturing Technology students is not consistent with the space limitations of the present study. Following is a description of the major equipment items in the CAM Laboratory.

- o a high performance Evans and Sutherland graphics system for use in process simulation and material flow studies;
- o fabrication equipment, including a 3-axis computer controlled milling machine used for undergraduate instruction and for some prototype production, and a Sheldon CNC lathe equipped with an Allen Bradley controller;
- o two material storage systems--an Eaton Kenway mini-load stacker and a White Company carousel unit--used in conjunction with the manufacturing program's plant layout and material handling course. The two systems are also used for storage of tooling and in-process inventory;

- o an ASEA industrial robot capable of welding, grinding, inspection, assembly and motor rewinding which is used in graduate and undergraduate projects;
- o a 3-axis Cordax Model 1000 coordinate inspection machine, which will soon be supplemented by in-process sensors--including laser scanning devices and equipment for measuring force, temperature, position, and velocity.

The CAM laboratory has three major uses: 1) teaching at both the undergraduate and graduate levels, 2) research and development conducted by faculty and students, and 3) demonstrations and seminars for faculty, students, and industrial visitors. All of the production machines in the laboratory are computer-controlled to facilitate the development of a demonstration system in which all of the equipment will be networked into a distributed manufacturing system via common data bases. To develop the proposed integrated system, the students and staff have set up a "CAM Mini-Lab" where they can test the integrated manufacturing process on a small scale before attempting to use the full-size industrial equipment. Current equipment in the Mini-Lab consists of the following:

- o an IBM-PC Graphic System used to retrieve a given part shape from a data file and to modify the basic dimensions to the required configuration. The output is then scaled and plotted on a hard copy device.
- o The part information is then transmitted directly to an Apple CNC Lathe controller that retrieves the cutter path routines to make the part.
- o A Microbot robot retrieves the part stock from an automated storage and retrieval system and inserts this part into the lathe chuck.
- o The part itself is then automatically produced on a miniature CNC lathe.

By December, 1983, a miniature computer-controlled milling machine, turret punch for sheet metals, and a newly designed robot will be added to simulate a fully integrated production facility.

Curriculum

Freshmen begin with a course on basic machine tool operation and an overview of the primary processes and materials used in manufacturing. They are also required to take basic graphics or drafting courses from the Design Technology division and an "Introduction to Engineering and Technology" course required of all technology students. Sophomore- and junior-year studies focus primarily on the manufacturing processes courses that form the backbone of the curriculum. These processes include machining, welding, casting, forming, molding, and heat-treating, and are supplemented by "related" technical courses in material science, fluid power, and electronic control, and "supporting" courses in computer sciences, mathematics, physics, economics, and technical writing. Sophomores and juniors also take courses in quality assurance, production planning, and machine tool performance.

While a number of the freshman- through junior-level courses include sections on computer-aided manufacturing techniques, machines, and processes--most notably, the numerical control course, which contains a lengthy section on computer-assisted programming--it is not until their senior year that students may begin to focus on the curriculum's "minor option" in computer-aided design or manufacturing. At that stage, manufacturing students interested in design or programming may take advanced CAD courses from the Design section or computer programming courses from the Computer Science Department. Those interested in computer-aided manufacturing may take courses in robotics, computer-aided materials handling, computer-aided manufacturing systems, advanced N/C programming, N/C software development, and group technology.

All of the manufacturing courses have an associated laboratory requirement, and students spend approximately 50 percent of their time in the laboratories applying the theoretical material learned in the classroom. All students are assigned a number of individual and group projects during the course of their studies. The projects are designed to foster analytical and creative problem-solving capabilities, to help the students understand the importance of proper design and good manufacturing planning, and to teach them how to work as part

of a development or production team. A number of these projects are conducted as part of a senior-level course titled "Manufacturing Development Lab," which is designed to be the culmination of the students' training. Students in this course are expected to use the concepts and skills learned in previous processes and planning courses to tool-up and produce usable products, to perform in-depth manufacturing analyses, or engage in other production and planning activities identical to those performed in industrial environments. Products produced by students in the development lab include an electrically-driven wheat mill and parts for a miniaturized turret punch press to be used in the CAM Mini-Lab, together with feasibility studies on the manufacture of the press. Students have also participated in joint projects with industry on plant layout and materials handling, machinability studies, and group technology and material classification and coding studies.

Enrollment Trends

Beginning with two students in 1960, the Manufacturing Technology program has shown a relatively steady enrollment growth over the past 2 decades. With a current enrollment of 180 students, the program is expected to reach its enrollment ceiling of 250 students by 1985. The manufacturing program has the lowest number of female students of all the technology programs (three women are currently enrolled) and the highest number of transfers from other departments. In fact, very few of the Manufacturing Technology students enter the program as freshmen; from 30 to 40 percent of the students transfer from one of the engineering departments while the remainder come from a variety of other colleges and departments throughout the University.

An on-going project within the Manufacturing section is the development and analysis of manufacturing student profiles. This study shows that most manufacturing students have had from three to five other majors before taking up Manufacturing Technology, have an average of 2 years of industrial experience, and are 26 years old when they graduate. A recent study of approximately 30 manufacturing seniors indicates a number of similarities among the students studied: their major interests were in mechanical things, seeing things work, seeing how things work, technical production management and supervision, and computer programming. Asked to assess their own abilities, the students rated themselves high in inventive ability,

visualization of interaction among various components of a process, ability to do practical, "hands-on" engineering, ability to organize and schedule projects, ability to make decisions when not all the facts are available, ability to work under pressure, and ability to work well with people.

Placement

From 95 to 99 percent of each graduating class of manufacturing technologists find jobs in industry. Most graduates receive multiple job offers at starting salaries that show a steady increase year by year. Although current salary information is not available, surveys of 1980-81 graduates show an average starting salary of \$23,500 with salaries ranging from \$21,000 to \$27,600.

The majority of graduates are employed in the automotive and aerospace industries, heavy equipment manufacturing, computer-related production, and in firms producing high-technology ordinance materials. Among the companies most active in hiring BYU Manufacturing Technology graduates are I.B.M., Texas Instruments, Ford, John Deere, Caterpillar, General Dynamics, General Electric, Hughes, U. S. Steel, Hewlett Packard, Boeing, Lockheed, and Cummins Engine.

A large proportion of the graduates are hired as manufacturing engineers while others are classified as industrial engineers, process engineers, design engineers, quality assurance engineers, research engineers, and production engineers. A significant number go directly into management--most as managers, some as management trainees. The remainder assume a variety of positions and are hired as trainers, estimators, N/C programmers, systems analysts, technical service representatives, production schedulers, and lab technicians.

Design Engineering Technology

The Design Technology program was not only the first technology program in the United States to award a baccalaureate degree in design and drafting* but it was also the first 4-year program to be certified at the Engineering Designer level by the American Institute for Design and Drafting (AIDD)** and, along with BYU's Manufacturing Technology program, the first 4-year technology program to be accredited by ABET.

As the field of industrial drafting and design adapted to computer-assisted techniques, the Design Technology faculty attempted, as best it could, to keep pace with the rapid industrial advances. By the early seventies, students in the Design Technology program were using APT part-programming language to complete manual programming and batch processing exercises, keying the manually produced programs onto a Flexiwriter which produced machine control tapes that were then verified on a Gerber plotter. At the same time, faculty members were actively exploring ways of automating the design graphics processes in the program by making contacts with industrial representatives, keeping themselves informed of the latest processes and their potential, and attending and speaking at professional gatherings. It was at one such professional meeting--an AIDD convention--that a Design Technology faculty member was approached by a representative of Applicon, a major turnkey computer graphics firm, who had been impressed by his presentation describing the Design program's attempts to incorporate industrial techniques into its curriculum. As a result of that meeting, Applicon eventually donated a computer graphics system to the Design program. The one-terminal Applicon system was installed in 1975 and the faculty began developing coursework to incorporate computer-aided design instruction into the curriculum. During the past 8 years, the relationship between Applicon and BYU's Design Technology

* According to the Design Technology faculty, many companies had been forced to employ graduate engineers to fill design positions because of industry's growing need for qualified technical personnel. The design faculty viewed this process as "counterproductive in view of the engineers' sophisticated training and interests" and developed the Design Technology program to produce graduate designers specifically trained to meet the industrial need.

** AIDD is a professional group organized to advance the state of the art in the industrial drafting and design community. The institute has an educational arm which certifies high school, technician-level (2-year), and baccalaureate (4-year) design programs.

section has remained strong and has resulted in the donation of two new Applicon systems (one of which replaced the original, already-outdated, system). In addition, because of the curricular advances made possible by the use of the Applicon systems for instructional purposes, Computervision, G.E.-Calma, and other CAD systems have either been donated by the producers or provided at a minimal cost to the college (see Facilities and Equipment, p. 24). The design curriculum currently taught at BYU would not have been possible had the faculty been less successful in maintaining industrial contacts and encouraging industry to donate equipment.

Program Goals and Objectives

The primary goal of the Design Engineering Technology program is to "expose the student to challenging opportunities in mechanical design, including new materials, techniques, processes, etc., and thoroughly acquaint him with the current trends, ideology, and tools of technical and computer-generated graphics." The educational philosophy that supports that goal is that "students must have a foundation in theory, coupled with viable applications experience, before education becomes truly meaningful." That philosophy, shared by the other sections of the Technology Department, sets the technology curricula apart from traditional engineering curricula and results in an instructional program in which fully half of the student's work is practical, "hands-on" experimentation and application.

Among the technical objectives of the Design program are the following: 1) to familiarize the student with basic problems in design development, including documentation and production techniques, precision dimensioning and tolerancing (among these techniques are computer-assisted design, parametric design*, and automation within the design cycle); 2) to teach basic computer-aided design, manufacturing, and engineering (CAD, CAM, CAE) principles; 3) to assist the student in becoming knowledgeable about the proper use of modern production tools, machines, and equipment; 4) to aid the student in learning the basic manufacturing processes and how to achieve economical production by

* See glossary.

selecting the proper process; 5) to acquaint students with numerical control systems and their applications, and 6) to provide students with opportunities to participate in actual industry-related design problems.

Faculty

All six members of the Design faculty have industrial experience in their specific areas of instructional specialization. In addition, a number of the faculty members combine their university teaching and research with industrial consultation, which helps them remain current with industrial practices. One faculty member, who spearheaded the department's computer-aided design activities, has done consulting work for Boeing Commercial Airplane Company, Ford Aerospace, General Dynamics, Via Systems, Computer Research Technology Corporation, the U. S. Navy, Department of Defense contractors, and various educational programs throughout the country. Three of the faculty members have master's degrees, two have Ph. D.'s, and one has an Ed. D. degree.

All of the members of the design faculty make a point of developing their own and their students' knowledge of computer technology within their areas of specialization, and the faculty as a whole has attempted to develop expertise in design specializations other than their own in order to provide "back-up instructor capability" for each of the courses in the curriculum.

Facilities and Equipment

At present, the Engineering Sciences and Technology Building houses four instructional laboratories containing interactive graphics and computer-aided design equipment. One of these laboratories, called "The Apple Lab," contains a total of 25 microcomputers (including 8 Apples) that are programmed to simulate many of the basic computer graphics functions of Computervision or Applicon systems. The Apple Lab is used to train freshmen in the technology and engineering departments in the basics of computer graphics. Students in more advanced classes use sophisticated industrial equipment located in the other instructional laboratories. That equipment includes two Applicon 885 multi-workstation IMAGE configured systems (eight workstations); a Computervision CADD 3 multi-terminal system; a Computervision CADD 4 multi-workstation system; a Calma DDM system, also multi-terminal; and a Tektronix 4054 system used principally by electronics students.

Curriculum

In contrast to the Manufacturing Technology curriculum--which stresses conventional manufacturing skills and knowledge in the beginning of the programs and moves gradually into computer-oriented processes on the senior and graduate levels--the design curriculum focuses on computer-aided techniques and applications from the outset.* All design students study seven principal areas--graphic science standards, problem analysis, planning, design synthesis, evaluation, documentation, and application--all supplemented by the computer systems in the school laboratories.

The design program builds on the basic design and drafting skills and knowledge developed in the required freshman and sophomore courses covering the fundamentals of engineering graphics, mechanical drafting (which includes automated drafting techniques), and principles of descriptive geometry. While computer-aided techniques are taught as part of individual lower-division courses, half of the required courses for juniors and seniors focus entirely on computer graphics and computer-aided design. Two of the six design courses required during the junior year, for example, are 1) "Professional Graphics Applications--Interactive Computer Graphics" and 2) "Computer-Aided Design--Interactive Graphics I."

Professional Graphics Applications reviews the development of computer graphics; covers the fundamental terminology, concepts, and principles of computer graphics; introduces the students to the uses and applications of 2- and 3-dimensional systems; and teaches operational techniques.

Students in this course study the capabilities and functions of Apple, Applicon, and Computervision systems and complete laboratory work focusing on operational techniques required by each system.

* This, according to Design program faculty, reflects current practice in industry, where CAD techniques are more widespread than CAM or CAD/CAM techniques.

Computer-Aided Design--Interactive Graphics 1 provides students with exposure to a broad range of engineering applications that can be executed on CAD/CAM systems; trains them to execute vendor-prepared applications packages dealing with engineering problems, and exposes them to CAD/CAM software development. Among the applications and techniques studied in this course are finite element modeling, digitizing, parametric programming, numerical control part programming, and detailing 3-D drawings.*

In their senior year, students are required to take two other computer-oriented courses:

Basic Computer-Assisted Part Programming provides students with a practical working knowledge of APT programming techniques; gives them a frame of reference to help them to understand and implement computer-aided design and manufacturing processes; and explores the impact of APT and automation in general on the traditional techniques and philosophy of engineering graphics.

Design Technology--CAD Software Development (Interactive Graphics 2) explores CAD software development research techniques, programming, and operation of automated and computer graphic equipment with the object of acquainting students with CAD databases and database manipulation tools.**

In addition to the required courses, two graduate courses in advanced computer-aided design and advanced CAD applications are open to seniors as elective courses (see Graduate Programs, p. 28).

* See glossary.

** Students are also required to take a non-credit "Design Technology Seminar" each semester. Seminars are held twice a month. Once each month the Design Technology students join with all students in the college to attend the Engineering College Lecture covering a recent topic in engineering; the other monthly meeting addresses recent developments in computer-aided engineering and is specifically geared for design students.

Enrollment Trends

The Design Technology program has the highest enrollment of the technology programs. In fact, with a current 1982-83 academic year enrollment of 574 undergraduates, the Design faculty is now in the position of having to introduce enrollment controls to eventually reduce the number of Design students to 300. The primary reason for adopting this measure is to enable Design students to spend a minimum of 5 hours a week working on the CAD stations. Approximately 30 of the Design undergraduates are women, giving this program the highest percentage of female enrollment of all the Technology programs.

A recent analysis of the enrollment figures (done when the enrollment totalled 555) revealed that 77 of the design students were freshmen; 119 were sophomores; 155 were juniors; and 204 were seniors. The relatively small number of freshmen and sophomores does not reflect an enrollment decline at the lower division level; rather, it reflects a general enrollment trend seen in all of the sections of the Technology Department of upper division transfers from other disciplines.

Placement

Like the other Technology programs, the Design program has a placement rate approaching 99 percent. With only occasional exceptions, those who do not accept immediate employment in the design field go on to graduate school or into the military. One reason for the high placement rate is that the faculty actively encourages students to work in industry to get application experience before going on to graduate work. Most students receive two or more job offers, and program graduates have been employed in the following firms (to list but a few): Sandia Laboratories, General Electric, Texas Instruments, Boeing, Applicon, Garrett Corporation, John Deere Product Engineering Center, Hughes Aircraft, General Dynamics, Signetics, United States Steel, Martin Marietta, Xerox Corporation, Calma Company, Bechtel Power Corporation, Westinghouse, Rocketdyne, and Motorola.

The majority of graduates are employed in engineering positions directly after graduation. Specific occupational titles assigned by the hiring companies include the following: design engineer, CAD applications engineer, process engineer, manufacturing engineer, CAD/CAM engineer, computer engineer, rocket

design engineer, software engineer, product design engineer, associate engineer, and engineer. Others are employed as CAD/CAM programmers, software analysts, tool designers, CAD support technologists, computer graphics specialists, and CAD/CAM consultants.

A number of graduates are hired as CAD or CAD/CAM managers or as management trainees, and a growing number are hired as CAD/CAM trainers. Another growing occupational opportunity for which Design graduates are well prepared is technical marketing support—a number of recent design graduates have been hired as technical personnel who accompany equipment salespeople to answer the customer's technical questions and to help them make realistic appraisals of whether or not CAD/CAM equipment will perform desired functions in specific environments.

Graduate Programs

In 1977, the Technology Department established an M. S. program in Computer-Aided Manufacturing. Now retitled Computer-Integrated Manufacturing (CIM), this program currently offers separate options in CAM and CAD and may in the future offer an option in computer-aided testing (CAT) for those students specializing in advanced electronics applications. The renaming of the CIM program not only made specific options in design and manufacturing available but also emphasized the thrust of the program, which is to provide students with training in the use of specific computer applications (as, for example, robotics and group technology) as the basis for the study of integrated manufacturing where a variety of computer-aided equipment is linked in a distributed system.

One unusual feature of the CIM program is that over half of its students are professional engineers and managers employed by the Western Electric Company, who attend condensed, intensive versions of the regular school-year courses for 5 weeks each summer over a period of 5 years (see pp. 33-34). The remainder of the students enrolled in CIM are full-time graduate students. At present, 30 full-time students and 60 Western Electric engineers are enrolled in the program. The first eight Western Electric students completed their coursework during the spring 1983 term.

In the fall of 1983, the Technology Department will offer another graduate degree program in technical management. This new program offering is the result of a cooperative effort between the College of Engineering Sciences and the School of Management and will combine MBA courses with technical electives from either the Technology Department or the traditional Engineering Departments. Students choosing to supplement management courses with Technology coursework will pursue the Technology Management option, while students electing to take coursework from the engineering departments will follow the Engineering Management option.

Since the Technology/Engineering Management program has not yet been offered, the remainder of this section will be devoted to the program in Computer-Integrated Manufacturing.

Program Goals and Objectives: Computer Integrated Manufacturing

The major goal of the Computer-Integrated Manufacturing curriculum is to prepare graduates to integrate computerized systems in manufacturing environments and to do so with a high degree of effectiveness. Specific objectives defined to support that goal are the following:

- o To instruct students in the principles, elements, philosophy, and techniques of effective manufacturing system design;
- o To add student in developing the ability to integrate computerized systems to solve practical, recurring problems;
- o To provide guidance to students completing the M. S. thesis requirement, which involves an in-depth study of a social, economic, or technical aspect of computer-aided manufacturing systems.

Entrance Requirements

The program is specifically designed for students with recent industrial experience who wish to develop specialized skills and knowledge in technical and managerial aspects of computer-aided manufacturing and design. Applicants must, therefore, have at least one year of relevant industrial experience.*

Other entrance requirements include 1) a Bachelors degree in Engineering Technology, or, with the consent of the department, a B.S. in an allied discipline such as engineering; 2) evidence of completed coursework in manufacturing processes, materials science, design and graphics, electronics, computer programming, physics, and calculus.

Faculty, Facilities, and Equipment

Graduate courses are taught by approximately two-thirds of the Technology faculty. Facilities and equipment are the same as those available to undergraduate technology majors.

Curricula

Both CIM options are structured to accommodate industrial requirements and to prepare students for advanced work in computer-aided design and manufacturing. While students may create individually-focused options within the two formal options (CAD and CAM), specified courses are required to form a foundation on which to base the individualized program.

CAM Option. Students choosing to specialize in computer-aided manufacturing take the following courses:

* The only exception to this requirement is that students who have completed a year of cooperative education experience (which, in actuality, is only 8 months of work experience) are eligible to apply. The technology faculty, however, actively encourages technology undergraduates contemplating this advanced degree to work full time in industry before applying in order to gain a practical understanding of industrial practices before beginning graduate work.

- o Computer-Aided Facility Design and Materials Handling--theory and application of plant layout techniques, emphasizing materials handling systems.
- o CNC Part Programming--programming techniques and requirements for the manufacturing of components on computer numerical control machining centers, emphasizing programming, applications, and software development.
- o Group Technology--classification theory and practice applied to workpiece-classification-and-coding and statistics, production in manufacturing cells*, design retrieval, and generative process planning* (all with an emphasis on computer applications).
- o Computer-Aided Manufacturing Systems--basic activities, elements, and principles of computer-aided manufacturing, including terminology, systems integration, architecture, data-base development, interfaces, and computer hardware/software requirements.
- o Industrial Robotics--history and philosophy of robotics, industrial applications, programming, economic justification, and integration with production systems.

Students are also required to take a course in computer-aided design (see below) and a graduate seminar, and may choose from a number of senior- and graduate-level manufacturing, design, and electronics technology courses or courses in computer science, mechanical engineering, or business management to complete their option.

CAD Option. Students taking the computer-aided design option are also required to take the manufacturing technology courses in Group Technology and Computer-Aided Manufacturing Systems. Two advanced CAD courses are also required:

* See glossary.

- o Computer-Aided Design: Interactive Graphics 3--CAD/CAM systems management philosophies, including systems evaluation, cost justification, procurement procedures, implementation, and management/operator training programs.
- o Advanced CAD Applications--philosophy, methods, and applications of engineering techniques pertaining to present and future trends of finite element and solids modelling; complex numerical control methods.

Elective coursework may be chosen from all three curricula of the Technology Department, the Computer Sciences Department, and the Mechanical Engineering Department.

Electronics Technology Coursework. Although there is, at present, no formal electronics option in the CIM program, a number of upper-level and graduate courses that focus on computer-aided applications and techniques are available to students in the CIM program. Among these are Computer-Aided Testing and Instrumentation, Electronics Fabrication and Assembly, and Real-Time Sensing and Control.*

Research

All CIM students are required to do research and write a thesis, preferably on a practical aspect or application of computer-integrated manufacturing systems. In practice, areas of research have been very broad. A number of students participate in on-going faculty research (see pp. 34-35), while others initiate independent research projects in subjects such as selection of CAD equipment, CAD training, CAD system performance, computer-aided materials selection, carbide selection, finite element modeling, automated steel mills, solids modeling, software quality assessment, and the cost of product quality and its relation to market share.

* The Real-Time Sensing and Control course focuses on writing computer language for computer operations that run in actual time (i.e., are not stored by the computer and computed in a batch mode).

The Western Electric Program

In 1978, Brigham Young became one of a handful of universities participating in Western Electric's "On-Campus Summer Program," which provides selected Western Electric employees with the opportunity to attend graduate school on-campus for 4 to 5 weeks during the summer for a 5-year period. While the other participating universities—including Clemson University, Kansas State University, New Mexico State, Purdue, Texas Tech University, and the University of Illinois—offer a variety of advanced courses, some of which focus on CAD/CAM, Brigham Young is the only one to offer a degree program in computer-integrated manufacturing. Although Western Electric does not require the 60 employees currently attending BYU to enroll formally in the Computer Integrated Manufacturing degree program, almost all have chosen to do so. Those who formally enroll in the program must complete the same thesis requirement as all regular CIM graduate students, and all of the Western Electric employees receive the same classroom instruction and laboratory practice. Each summer, two courses from the CAM option are restructured to fit into an intensive 5-week period so that students complete the equivalent of two 14-week courses. The first eight graduates completed their studies in the summer of 1983, and two or three additional students will complete their degrees by the end of the year.

Western Electric covers all of the students' formal costs—including fees, tuition, housing, and books—and also reimburses BYU for the salaries of the Technology faculty and staff, and for equipment use and maintenance.

Enrollment Trends, Attrition, and Placement

While the number of Western Electric engineers officially enrolled in the CIM program has gone as high as 60, academic year enrollment is limited to 30. Of the 30 students currently enrolled in the academic year program, approximately two-thirds are graduates of BYU and over half are graduates of BYU technology programs. Many CIM students take leaves-of-absence from their companies to take the coursework and attempt to complete the thesis requirement after returning to their jobs. This practice is the primary cause of attrition (approximately 33 percent), which primarily occurs after the coursework has been completed and when students return to work rather than remain on campus

to write their theses. The placement rate for CIM graduates, on the other hand, is 100 percent. Average entry level salaries received by CIM graduates range from \$27,000 to \$33,000, although some program graduates have received offers as high as \$50,000.

Faculty Research

Among the research opportunities available to students are projects conducted by the faculty, most of which have a strong industrial orientation. A number of projects developed by senior faculty in the Manufacturing program have received national attention and a significant amount of industrial support.

DCLASS. One such project—ongoing for some 10 years—resulted in the development of a software package called DCLASS (Decision Classification Information System), a hierarchical decision-tree processing system and tree definition language that can be used for classifying and retrieving parts, materials, processes, equipment and tooling. The basic philosophy behind DCLASS is that users can make better decisions when their options are clearly defined. The hierarchical trees that form the basis of DCLASS are high-level logic structures that allow various decisions and actions to be defined—decisions like, what is the best shape for a particular part? what material should it be made of? what manufacturing process should be employed to create the part? what equipment and tooling should be used? For each step in each process, the user's options are clearly shown on a computer menu. He then selects the option of his choice and is automatically branched to the next portion of the tree and new options are presented to him. This procedure is repeated until the item or process is described in full. DCLASS is also an integration tool which makes networking—the passing of data back and forth between different systems—possible.*

DCLASS is now licensed for use at some 50 plants, including Boeing, Cincinnati Milacron, Texas Instruments, Westinghouse, Grumman Aerospace, Hewlett Packard, Sperry, Hughes, U. S. Steel, Tektronix, Xerox, Eaton, and United Technologies. Since DCLASS is a general purpose decision-tree-

* Professor Dell K. Allen, "Computer-Aided Simulation Training System"

processor, it can accommodate any classification and coding scheme, so that each company can tailor the coding logic to its specific codes and operations.

CAST. Another project, supported by a grant from the Society of Manufacturing Engineers and by a consortium of companies and educational institutions, is the Computer Aided Simulation Training System (CAST). Eventually, the students, staff, and faculty working on this project will produce 250 training modules covering the major manufacturing processes, and an additional 50 modules on advanced process mechanics and systems, experimentation, modeling, and simulation. Each process module will provide a definition, show a schematic of the particular process, typical equipment, and tooling used. Additional short motion sequences will illustrate each process in operation.

CAST makes use of the hierarchical information trees that form the basis of DCLASS along with a microcomputer-controlled videodisc and a voice synthesizer. Other features of the CAST system include 1) the ability to automatically correlate employee skills with pre-established job requirements to generate an individualized training sequence and 2) incorporation of evaluation and testing logic to re-direct the user to instructional sequences not mastered during the first exposure.* While many of the processes to be taught via the CAST system will be conventional manufacturing, others will be computer-aided processes--examples include robotics applications, group technology, and systems integration. Potential users of CAST are in-plant trainees and students in manufacturing programs at educational institutions.

* The modules just described--called Level 1 modules--are for use by operators in manufacturing plants and by beginning manufacturing students. Also being developed are Level 2 modules of these processes--application modules--which will help industrial designers learn what rules or principles relating to the process they must know to design a product (an understanding of machine motions and tool shape, for example, along with many other principles). Level 2 modules for Manufacturing Engineers include such rule-selection and rule-using information needed to plan for, design, implement, and control a given process. Level 2 for Industrial Engineers provides information needed to estimate production times and costs. Level 3--for "rule-finding"--helps students and engineers to discover the rules and principles that govern each process or family of processes. These rules can then be applied to Level 2 applications.

Both DCLASS and CAST were developed under the auspices of the Computer-Aided Manufacturing Lab. The staff and students working in the CAM Lab also work on projects involving the use of the CAM Mini-Lab (see p. 16) to test automated processes on a small scale, a computer-aided process planning system, and the application of computer-aided techniques to quality assurance.

A number of design students participate in software development projects. One project creates software training packages for use on Apple computers which simulate some of the interactive graphics functions of more sophisticated systems dedicated to computer-aided design and drafting. Others are working on a project to network CAD equipment to computer numerical control machines. Still others work on a project to write user-oriented software for Computervision and other computer-aided design systems contained in the design labs.

III. INDUSTRIAL AFFILIATIONS

The Technology faculty operates on the philosophy that, in meeting the needs of industry, it is meeting the needs of its students. The discussion in the preceding section has brought out a number of ways in which the faculty has sought industrial advice, secured industrial donations, and engaged in research that is either industry-oriented or conducted in cooperation with industry. The following paragraphs describe specific formal channels through which the Technology Department communicates with industry and discusses the department's position on the formation of an industrial advisory council.

Channels of Communication

The Technology Department participated with the other departments in the college to form the Alliance with Industry Program in 1981. The 20 companies who participate in the program* each provide an annual contribution of \$10,000 or more to support the college's research and educational programs. Benefits to the industrial partners include the following: 1) licenses for software

* These include B. F. Goodrich, Boeing, Digital Equipment Corporation, Evans and Sutherland, Garrett Corporation, Hewlett Packard, EXXON, G.E.-Calma, Genrad, G.T.E., and Computervision.

developed by college faculty (including high-resolution graphics software developed by a member of the engineering faculty, 2) research results in methodology and applications, 3) help in solving special industrial problems, 4) seminars for technical personnel, and 5) access to BYU graduates skilled in computer-aided techniques. Benefits to the college, aside from donations of funds and equipment, include industrial advice and interaction and the opportunity to do research on current industrial problems.

Apart from its participation in the college-wide alliance with industry, the Technology Department has also formed independent alliances. Each year, the department holds two DCLASS conferences, one for users who have licensed the software and one for non-users who are considering purchasing a license. The users conference provides a forum for the exchange of ideas and the presentation of new DCLASS applications; the non-users conference includes an initial orientation followed by demonstrations, workshops, and presentations by industrial representatives who use DCLASS and by Technology Department faculty.

The Manufacturing Consortium that supports the development of CAST holds twice-yearly meetings to review and approve the instructional modules as they are completed. The industrial members of the consortium also provide financial resources and technical information on the manufacturing processes which are the subject matter of the instructional packages, and the educational members write the software, participate in the review process, and help to evaluate the teaching/learning process employed.

The Western Electric program described on p. 31 gives the Technology faculty an opportunity to work intensively with engineers and technical personnel, and faculty leave programs allow faculty members to renew their working knowledge of industrial practices by accepting short-term employment in industry. In addition, all faculty members take at least one trip a year to attend meetings of professional and technical societies. Another fruitful channel of communication is provided by industrial visitors. Literally thousands of industrial representatives visit the department each year--some to view the facilities and equipment, some to deliver or attend seminars, and many to ask advice on computer-aided equipment and methods.

The Advisory Council Issue

None of the programs in the Technology Department has formed an industrial advisory council, in spite of lobbying by curriculum accrediting agencies for the programs to do so. The position of the department as a whole is reflected in the following passage, excerpted from the Design Program's report to the Accreditation Board for Engineering and Technology:

Several factors influenced the final decision (not to form an advisory council):

1. The student body is largely made up of people from locations other than Utah.
2. Graduates typically seek employment outside of the State of Utah because their homes are elsewhere and also because Utah's agricultural base does not lend itself to relevant, or related job opportunities.
3. An Advisory Committee selected from local industry would likely reflect only local needs, which may not be consistent with the broader spectrum of a national clientele.

Department representatives point out that, in effect, the graduates of the various technology programs serve the department in an advisory capacity. Alumni are sent questionnaires at regular intervals, and a large number of them reply. In addition, the employers who hire co-op students also provide practical assessments of the strengths and weaknesses of those students, which are used by the faculty to gauge the strengths and weaknesses of the curricula.

IV. EVALUATION OF PRESENT AND FUTURE CAPACITY

When asked to evaluate BYU's technology programs on the basis of the skills and ability of their graduates, one employer replied: "On a scale of 1 to 10, I'd rate them 10." Other employers contacted agree, noting that BYU graduates not only have "just the right education" and that they often require less on-the-job orientation training than traditionally-educated engineers, and that they are also more mature and more willing to work extra hours and at odd hours than most engineers fresh out of college.

The Rocky Road to Success

Evaluated with respect to its own stated goal of preparing students for positions requiring applied engineering, process planning, and systems management skills, the BYU Technology Department clearly is highly successful. Its present capacity to provide its students with the CAD and CAM skills sought by increasing numbers of industrial firms is perhaps best described by the adage, "success breeds success." Because the faculty has been able to obtain industrial donations, state-of-the-art equipment, industrial advice, and real-world research problems for its students to work on, BYU technology graduates are sought after by industry. And because of the graduates' success in industry and the faculty's achievements in research, the Technology Department now has more offers of equipment and industrial research projects than it can handle and is in the position of giving advice to companies less technologically advanced than it is.

A look at the history of the Technology Department since its inception in 1960, however, reveals that its present-day success story grew out of a Cinderella tale. When the baccalaureate programs were first established, and for many years afterwards, the members of the Technology faculty saw themselves as "underdogs." They were looked down upon by many of the engineering faculty, unrecognized by most of the rest of the University, and their 4-year programs were often confused with the 2-year technician programs also offered by the Technology Department at that time. Industry-oriented and intent on filling the gap created by the increasingly theoretical focus of traditional engineering education, the Technology Department resisted promptings by engineering societies, accreditation agencies, and some of the college faculty to "add more courses the students wouldn't need in industry in order to become accredited--it wasn't worth the trade off."

Eventually, the manufacturing and design programs--which substituted application-oriented, laboratory-based courses for the most highly theoretical coursework in engineering disciplines--became the first accredited technology programs in the country. Although accreditation was beneficial to both the students and the faculty, it did not solve their problem of being looked upon as either second-rate engineers or as super-technicians. However, the department's industrial focus and the faculty members' desire to prove that neither they nor the discipline of technology were "poor relations" were significant factors in the department's early concentration on computer-aided design and manufacturing. Because the programs were designed to teach state-of-the-art industrial skills and applications, the faculty began exploring ways of obtaining equipment and incorporating programmable automation into the curricula approximately 10 years ago when it became clear to them that CAD and CAM would eventually become required fields of knowledge. Furthermore, because the programs' curricula were not bound by engineering accreditation requirements, which allow little space in a 4-year curriculum for the inclusion of new courses, coursework focusing on CAD and CAM could be incorporated into the technology curricula with relative ease.

The final hurdle for the Technology Department was industry itself. Faculty members went from company to company in the early seventies, but did not succeed in obtaining donated or reduced-price equipment until they proved their genuine interest and capability by demonstrating to Applicon that their students were doing all that could be done to automate the drafting courses with the limited equipment at their disposal. It was at this stage, when the department received its first major donation (the Applicon CAD system) that Cinderella was allowed to try on the glass slipper. The other slipper--a \$130,000 Kerney & Trecker CNC milling machine, which the company sold to the department for \$50,000--was fitted shortly thereafter. These two significant equipment additions enabled the faculty to begin to incorporate sophisticated computer-aided techniques into the coursework and also encouraged other firms to donate funds and equipment.

Technology and Engineering: Interdepartmental Relationships

Once it "proved itself," the situation of the Technology Department improved both inside and outside the University. Although perfect concord between engineering and technology faculty members is not always achieved even now, the vast majority of faculty members in the College view engineering and technology as partner-disciplines, both of which are necessary to provide the broad spectrum of education and training required to prepare graduates for engineering and engineering-related positions in industry. Civil, Mechanical, and Electrical Engineering students are now required to take Design Technology courses, and many engineering students take courses from all three technology programs as technical electives. Technology students were always required to take engineering courses relevant to their major program and a third to a half as many physics, chemistry, and mathematics courses as engineering students. There has been limited discussion about increasing the number of statics, dynamics, and strength of materials courses taken by technology majors to equal those taken by engineers, and there is some discussion about increasing the numbers of physics and mathematics courses in the technology curricula.* As the commonality between technology and engineering curricula grow, more and more students and faculty perceive the difference between the two disciplines to be one of approach and mission, rather than one of level of education.

Computer-Aided Engineering, Design, and Manufacturing (CAEDM) Committee

Both Technology and Engineering faculty now feel that they have an excellent relationship with each other, in contrast to the situation in many other universities which have both programs. The CAEDM Committee, created in 1980, provides a formal channel of communication between the technologists and engineers, and a number of professors in both departments coordinate research projects in which technology and engineering graduate students work together as part of a research team. College faculty believe that this team approach

* There is some disagreement among the Technology faculty on the issue of increasing the math and physics courses, which would entail either extending the Technology curricula beyond the limits of 4-year programs, requiring students to take more courses each semester, or dropping courses that the majority of the faculty consider to be essential for technologists.

has a great deal of significance for academia and industry alike.* The BYU Technology Department--whose primary focus is on the implementation of engineering designs--has been instrumental in increasing the engineering departments' awareness of the need to produce industrial designers who are more cognizant of manufacturing concepts and requirements. One tangible example of interdepartmental cooperation in this area is a CAEDM-sponsored short-course for faculty and students delivered by a representative from General Electric Company, which has instituted a version of a Japanese procedure that rates engineering designs on the basis of ease and efficiency of assembly. Another example is the work now being done in the CAM Mini-Lab, where electrical and mechanical engineering students, computer science students, and technology students all participate in projects addressing the manufacturing process from design to production and the problems of networking diverse CAD and CAM equipment.

The Technology Department also stimulated the engineering departments' interest in CAD and CAM, which, in turn, was a stimulus for the current focus on Computer Aided Engineering (CAE). The college as a whole has also benefitted from the industry interest generated by the Technology programs and graduates. Much of the computer-aided equipment obtained by the Technology Department serves the entire college, and the engineering departments have now obtained computer graphics and computer-aided data acquisition and analysis equipment through industrial donations and cooperative agreements with equipment manufacturers. In addition, the growing reputation of the Technology Department in industrial circles has brought in interviewers from across the country who hire engineering as well as technology graduates.

The Alliance with Industry program, formed under the auspices of CAEDM, brought the University \$1,858,000 in industrial equipment and in funds used to augment the computer-aided capabilities of the college. In April of 1983,

* A perennial problem in industry has been lack of communication between engineers who design the products and the manufacturing departments responsible for production. Because of this lack of communication, and because engineers normally receive little formal education in the requirements of the manufacturing process, industrial designers often fail to take manufacturing requirements into account when designing a product--a procedure that can lead to loss of money, loss of production time, or (in the worst instance) a product which cannot be manufactured.

CAEDM hosted a conference for 380 representatives from 120 universities across the country who are either planning or developing programs in computer-aided manufacturing, design, and engineering. Thirty speakers from 25 universities that have initiated such programs gave presentations on the approach taken at their respective institutions; and all of the participants had the opportunity to discuss common problems, individual experiences, and appropriate strategies. The object of the conference, called University Programs for Computer-Aided Engineering, Design and Manufacturing (UP CAEDM) was to increase communication among universities and to provide impetus for the implementation of teaching and research programs in CAD/CAM/CAE.

Problems

While cooperative endeavors like those mentioned above have brought the faculty of the technology and engineering departments together, the college is not entirely free of the traditional misunderstanding among engineers and technologists. Some of the Technology faculty still bear the scars of old battle wounds and refer to the "arrogance" of the engineering discipline as a whole, to the "old boys' club" atmosphere that links engineers nationwide and excludes technologists, and consider their own college education in traditional engineering schools to have "mistrained" them for industrial occupations. Some engineering faculty, on the other hand, resent the fact that most Technology Department graduates are classified as "engineers" when they move into industry and fear that such graduates may be "misrepresented" as degreed engineers. Another problem for the engineering faculty is that a number of visitors from industry and academia overlook the computer-aided engineering facilities and devote their entire attention to the CAD and CAM facilities of the Technology Department. The resentments on both sides are, however, gradually being overcome by the spirit of cooperation that now exists within the college and are but pale reflections of national tensions between technologists and engineers.

Technology Department Faculty Requirements: Benefits and Problems

The separate criteria developed for engineering and technology faculty members are indicative of the college's recognition of the inappropriateness of traditional university hiring, promotion, research, and leave policies for

those engaged in teaching a discipline closely associated with industry. The Technology Department's hiring criteria--which include industrial experience, computer background (preferably in CAD or CAM), and some teaching or training experience--ensures that faculty members have first-hand knowledge of industrial practices. The substitution of "professional development leave"--which may be taken for work in industry, for doctoral work in a university, or for work on research projects--for the traditional sabbatical leave gives faculty members the freedom to gain current industrial experience without jeopardizing their chances for tenure, as does the department's research and publications policy, which focuses on practical research and accepts as publications such work as laboratory manuals and papers on teaching methods and curricula.* Work experience during professional leave is not only acceptable, but it can also be used as the basis for a salary increase. Another distinguishing feature of the professional-development-leave policy is that such leaves are taken more frequently than sabbaticals--most often, every 2 years. This, given the rapidity with which technology is advancing in industry, is an obvious benefit to instructors whose mission is to teach state-of-the-art methods and practices.

The above-mentioned policies and practices have created a faculty that is especially well-suited to teaching in the field of programmable automation on the undergraduate and masters-degree levels and whose members' industrial experiences have given them the flexibility to teach a broad spectrum of courses within the three major programs. Nevertheless, some problems do exist. The most significant of these is the difficulty of finding candidates who combine industrial skills and experience with the required educational background and the willingness to accept an academic salary. This problem is further complicated by the religious orientation of the University. While LDS Church membership is not required of applicants for faculty positions, the life-style and general educational policies of the University are governed by the standards of the Church. As a result, the vast majority of the faculty belong to the Church (97 percent of the University faculty; 100 percent of the Technology faculty). What this means in specific reference to the Technology

* According to an associate dean of the College of Engineering Sciences and Technology, the college as a whole does not have a "publish-or-perish" policy. Instead, it has a "publish-or-it's-difficult-to-get-promoted" policy.

Department is that its pool of applicants--already limited by the unusual combination of industrial and educational background and experience required--is further limited by the need to find applicants comfortable with and supportive of the University's LDS orientation. The Masters' Program in Computer Integrated Manufacturing was originally designed with the intent of training both CAD/CAM systems managers and future educators--both for BYU and for other technology departments. Only three graduates of the masters' program, however, have gone into teaching; and although some of BYU's junior faculty members are products of the program, it has not provided a substantial number of faculty applicants.

Problems also exist for individual faculty members, especially junior faculty pursuing promotions and advanced degrees. Although a Ph.D. is not required for promotion within the department, the overall University policy places a premium on advanced research and doctoral degrees for advancement in rank. Thus, although Technology faculty without Ph.D.'s are not in danger of losing their positions, it is difficult for them to obtain promotions. Another problem for faculty members who do wish to pursue doctoral degrees is that there are relatively few universities where one can do Ph.D.-level work with the practical orientation that would be most in tune with their interests.

Working with Industry

Having designed its programs to respond to industrial needs and having concentrated on industrially-oriented research, the Technology Department is now able to work with industry on many levels. The continuing success of the Western Electric program and the satisfaction of the Western Electric employees who attend the summer sessions indicate the suitability of the technology curricula to current industrial needs, as do the multiple job offers received by technology graduates. The growing number of companies purchasing DCLASS licenses and exhibiting interest in the CAST system indicate that the research performed by Technology Department faculty and students also fills an industrial need. Some faculty members, in fact, are in the position of being able to pick and choose from a large number of potential industrial research projects. Because of the similarity of interest between Technology Department faculty and professionals in industry, and because of past success in research aimed at solving current industrial problems, individual faculty

members have been able to engage in long-term research projects resulting in a number of shorter-term benefits to industry. DCLASS, for example, is now put to use by a number of firms for classifying and retrieving information and for generating process plans, time standards, and a number of other applications. At the same time, the creator of DCLASS is conducting long-term research into the potential use of DCLASS as a systems integration tool. Revenues from the sale of DCLASS licenses have helped to buy equipment and renovate facilities and may soon be augmented by the sale of CAST training modules and the CAD training aides that allow Apple computers to simulate interactive graphics systems. In many instances, the department has been able to save the expense of maintaining computer-aided equipment by writing software programs for equipment vendors in exchange for maintenance services.

The major problem-area still remaining for the Technology Department in respect to working with industry is the attitude taken by some firms toward the occupational categories appropriate for technology graduates. This is discussed in the following section.

Technology Undergraduates: Progress and Problems

None of the four Manufacturing Technology undergraduates interviewed had enrolled at BYU with the intention of becoming technologists. One, in fact, had "never even heard of a manufacturing engineer" before he "stumbled" onto the Technology Department. Three of the students had transferred from other departments and majors (business management, pre-med, and geology) and one had not declared a major. Only one of the students had been referred to the department through formal counseling and guidance channels; the others heard about it through friends or other informal channels.

In sharp contrast to the apparent indecision and casting-about characterizing their early University experience is the students' satisfaction with their current field of study. All of them cited the excellence of the laboratory equipment, the practical orientation of the program and the opportunity to engage in "hands-on" laboratory work as the major reasons for their satisfaction with the program. The following comment by one of the students characterized the major benefits of the program from the students' point of view and elicited general agreement from the others: "The hands-on work helps with problem solving. We won't work in a foundry after we go to work, or weld

anything, or do actual metal forming, but we will be problem solving with tool design. We're built on a strong foundation--that's what's nice about our processes. Then we grow from there. We'll have to recognize what comes out of those (manufacturing) processes once we get to work." Other strengths cited by the students include the overall excellence of the faculty, the feeling of cohesiveness among the students resulting from the small size of the program and commonality of interests among the students, the assurance of getting a good job, and a feeling of "excitement" in preparing to work on national problems such as productivity and product quality.

Among the problems cited were the small size of the laboratories ("too many people trying to use the same equipment"), difficulty in making appointments with individual faculty members, and part-time faculty (who work full-time in industry) whose classes were not as "high quality" as those taught by the full-time faculty. The students were, however, quick to point out that the new Technology Building would solve the laboratory problem and that the faculty did "make time" to see them--making meetings with faculty members "difficult, but not impossible."

Another set of problems had to do not with conditions within the department, but with the University community at large and with potential employers. The students agreed that the department has a stronger reputation outside of the University than inside the student community. Some felt that the hands-on emphasis gave them the reputation of being "grease monkeys" and others mentioned the general lack of knowledge on the campus about what they actually did. Although the internal problems tend to set them apart from much of the rest of the campus community, they are of less concern to the students than their "frustration" with industry interviewers who, from the students' perspective, do not know "what we have to offer." The major cause of frustration is the knowledge that some companies would "take a mechanical engineer instead of us and then train him in what we already know how to do." This problem, however, does not exist in all companies, and it decreases as the department's reputation grows. One past graduate, who has now returned to BYU as a Technology Department faculty member, said that, while a relatively small minority of graduates are relegated to technician status, he himself was hired as an engineer and was promoted over the heads of new hires with engineering degrees because he needed less on-the-job training than

traditionally educated engineers. Surveys conducted by the Technology faculty show that this latter type of experience is the norm.

Future Capacity

Judged by its present success, the direction of the faculty's research, and its determination to maintain its awareness of industrial needs and techniques, the future potential of the Technology Department to continue producing well-trained graduates versed in computer-aided techniques and familiar with a wide range of computer-aided equipment seems high indeed. The major limitation is the small size of the department—which, because of enrollment control, will become smaller yet—and difficulties encountered in managing the growing numbers of computer-aided systems, which entail coordinating frequent upgrades and updates with the student need for equipment time.

Although College and University administrations have been generous in assigning funds to upgrade old facilities and build new ones for the technology and engineering departments, the Technology Department's resources cannot expand to accommodate all of the activities it would like to engage in. For example, a number of companies have requested that the department operate programs for their employees on the model of the Western Electric program. The department has had to turn down these requests for lack of resources. It will, however, attempt to offer a series of 2-day to 1-week seminars for industrial employees focusing on computer-aided design and manufacturing.

A general policy of the department and of the University is to sacrifice size for quality. The new enrollment control procedures, for example, will effectively close off enrollment for the Design Program for the next year or two, but will also result in more CAD-terminal-time for those students already enrolled. Of the three technology programs, Manufacturing exhibits the greatest capacity for future enrollment growth (student interest has been fueled by the national interest in productivity and the potential of computer-aided manufacturing), while the Electronics Program has the greatest potential for expanding its curriculum to include new courses focusing on computer-aided equipment and techniques. The Electronics faculty has already acquired six HP87XM computer-aided test stations to be used as personal instrument systems,

and a Tektronic 4054 computer graphics system for printed circuit board design. Future departmental plans call for an ECAM (Electronics-CAM) mini-lab to be established in the new Technology Building when it is completed.

The Technology Department, in cooperation with the Mechanical Engineering Department and the Electrical Engineering Department, developed a proposal for a 3-element graduate program in manufacturing systems in response to IBM's announcement that it would provide college and university grants for the development of new curricula in manufacturing techniques. BYU has received notice that it has been awarded an IBM 4341 computer system with 10 CADAM graphics terminals. This system will have a significant impact on the capacity of the three departments and of the college as a whole to train more students than they can presently accommodate.

The Technology Department's potential capacity to provide education in programmable automation is not entirely limited by the size of the department, if one considers the indirect impact of the programs as models for other schools, the willingness and ability of the faculty to provide information to academia and industry alike, and the potential of the Computer-Aided Simulation Training packages and the CAM-Mini Lab concept.

BYU Technology Programs as Models for Other Educational Institutions. The Manufacturing Technology Program has been used for many years by the Society of Manufacturing Engineers as a recommended model for 4-year manufacturing programs. In addition, representatives of 15 - 20 colleges and universities visit the BYU Technology Department each year with the expressed intention of creating their own programs on the BYU model. Technology Department faculty representatives offer the following comments on the feasibility of such attempts. While they have personal knowledge of a number of successful programs modeled on their own, they point out that the crucial requirements for a program like theirs are often met only with difficulty. The first requirement, from their point of view, is the necessity of "giving up the title of manufacturing engineering in order to give industry what it really wants." This is a step that a number of engineering schools do not wish to

take.* Once this step is decided upon, other pitfalls exist. One such pitfall is the tendency of some schools to place manufacturing technology programs in the department of mechanical engineering and to offer it as an option. The danger here, according to BYU faculty, is that the technology program is then likely to become a watered down engineering program rather than a parallel-track program. Another necessity is that each course in the curriculum be accompanied by an associated laboratory requirement. This means, of course, that appropriate equipment and facilities be available. Another major requirement is that the faculty have industrial experience and be comfortable teaching a less theoretical, practically oriented curriculum. The final requirement is interest on the students' part. While faculty can help to generate that interest, it could be difficult to do so in a strong traditional engineering college where students are bent on becoming degreed engineers and have little interest in less theoretical studies.

Technology Transfer. The Technology Department--and, especially since the formation of CAEDM, the college as a whole--has been, and will most likely continue to be, an excellent conduit for technology transfer. The faculty demonstrates a strong determination to continue to learn from industry and an equally strong desire to share what they have learned and their methodology of teaching it with other educational institutions. The UP CAEDM conference, in particular, has the potential of becoming a regularly occurring event: the second such conference is being hosted on the East Coast by Lehigh University in 1984. If that potential is realized, BYU will have provided the impetus for a sorely needed forum for continual exchange of information.** Technology Department faculty also express the intention of continuing the present

* According to one Technology instructor, "You can't take a true-blue theoretical engineer and expect him to teach technology; if you do, there's a danger that the faculty will make the technology courses too theoretical and the students will wind up with a pseudo-technology degree."

** An informal survey conducted by this researcher of selected colleges and universities revealed an astonishing lack of knowledge about the activities of other institutions on the part of faculty members actively engaged in planning or developing CAD/CAM programs. While some faculty members contacted did have some information about existing programs in colleges and universities, they often did not know the direction and focus of those other programs or had inadequate information about specific research and curriculum development activities.

practice of working as consultants to industrial firms and government agencies and of providing informal advice and services to industry representatives who visit the Department to obtain information on CAD/CAM systems and applications. Thus, the technology transfer provided by the Technology Department and other departments in the college is likely to continue to operate on multiple levels to the benefit of BYU, other academic institutions, and industry.

Computer-Based and Computer-Aided Instructional Packages. As modules of the Computer-Aided Simulation Training System (CAST) are completed and approved by the Manufacturing Consortium, they will be made available to industries and educational institutions for a minimal fee (covering the cost of reproduction and mailing). The Manufacturing Technology professor responsible for developing and coordinating the project is hopeful that within the next year, videodisc technology in the U. S. will be well enough advanced to allow the CAST development team to produce the training modules on interactive videodiscs. At present, a demonstration videodisc has been produced for use in further research studies on interactive instruction, and sound-slide presentations of some of the modules are being tested in manufacturing technology classes at BYU. The CAD training package for use on Apple computers is also in the development stage, and one of the Design Technology faculty has formulated a concept for computer-aided CAD instruction which he hopes to develop in the near future.

CAM Mini Lab. Technology Department faculty are also seeking funds to enable them to build duplicates of the miniature factory contained in the CAM Mini Lab and to provide them to 20 universities across the country. The recipient universities would be encouraged to attend "software exchanges," whereby advances made by one party would benefit the group as a whole. The estimated cost of producing the hardware for one mini-lab is \$50,000, which is equal to or less than the cost of many single items of computer-aided equipment.

Projects such as those mentioned above expand considerably the department's potential capacity to have a direct effect on education and training in the field of programmable automation. The DCLASS users and non-users conferences, the Western Electric Program, and short courses for professional engineers offered by the engineering departments further expand the college's ability to reach beyond the University campus to provide educational opportunities to working professionals.

APPENDIX A
ENGINEERING TECHNOLOGY EDUCATION

In a 1972 report on engineering technology education, the American Society for Engineering Education (ASEE) described the relationship between engineers and engineering technologists in terms quite similar to those employed by BYU representatives. In summarizing the central objective of engineering technology education, the report states:

"The central purpose of engineering technology education (is) support for the practical side of engineering achievement with emphasis upon the end product rather than the conceptual process. There are many overlapping areas, but, in broad outline, the engineering technologist may be said to help achieve what the engineer conceives. The technologist is usually a producer, the engineer is more often a planner. The technologist is valued as an expeditor, the engineer is sought as an expert. . . The development of methods or new applications is the mark of the engineer. Effective use of established methods is the mark of the technologist. The engineer's interest and attention must carry through to the final product of his creativity and its effective use. However, it is no longer necessary that he perform all of the technical functions from conception to completion of a new product or process and then exercise the continuing technical controls. The engineer's most important work is usually concentrated in the early stages of a project. The engineering technologist may perform similar activities to those of the engineer but at a different and usually later stage in the progression from conception to product..." (American Society for Engineering Education, Engineering Technology Education Study: Final Report, January 1972, p. 14.)

The factors influencing the creation and growth of bachelor's degree level engineering technology programs derive from many sources. According to the ASEE report, among those factors are "Changes in engineering education, trends to extend engineering technology programs to four years, ... the emergence of industrial technology programs from the area of industrial arts teacher education, and changes in the social-technological environment itself..." (p. 4). Industrial need is another factor:

"There seems to be a consensus that for the next movement upward in production, industry will need an increased input of technicians and technologists... This need will be partly engineered by volume of product, but it is being enhanced by growing sophistication of equipment and processes that demand more than vocational skills for construction, installation, operation, production and maintenance. Technologists will also be used for standardized design, in sales, and in supervision of production, including opportunities in management" (p. 39).

The experience of BYU's engineering technology graduates has borne out the 10-year-old prediction contained in the AS2E report. Those graduates are now employed in such positions as manufacturing engineers, production engineers, design engineers, production schedulers, process engineers, systems analysts, CAD/CAM systems managers, and technical marketing support personnel (see pp. 19 and 26).

APPENDIX B

ELECTRONIC ENGINEERING TECHNOLOGY: BYU TECHNOLOGY DEPARTMENT

BYU first offered an associate degree in Electronics Technology (ABET) program during the 1958-1959 school year. The first graduating class was in 1960, and the program first received ABET accreditation in 1967. The baccalaureate degree program was approved in January of 1968 and, in 1969, the first Bachelor of Science level class graduated. ABET accreditation was granted to the bachelor's-level program in 1971. The lower division program is quite traditional in nature, and the upper division course work is built upon that conventional base. The program structure thus provides for transfer students coming from 2-year accredited community colleges programs to begin at the junior level and continue toward the Electronics Engineering Technology degree.

Recent program improvements include emphasis in the fundamentals of computer programming, digital and microprocessor principles, and computer aided analysis and testing. The senior level core is now more structured in nature and requires all seniors to take classes in real-time executives, data transmission, control systems, and fiber optics.

Program Objectives and Rationale

Since the electronics and computer industries are some of the largest industries in the country and since many opportunities exist in these industries, the Electronics Engineering Technology Program is designed to give the student opportunities for individual development and growth and to prepare him or her with the latest knowledge and skills to perform as an electronics engineering technologist in the areas of analysis, design and development, construction, testing, and application.

The basis and philosophy of Electronics Technology education at BYU is that students must have solid theoretical knowledge coupled with application of this knowledge to make their education truly meaningful.

The following are some of the specific technical and professional objectives which the Electronics Technology department uses as a guide in curriculum development and planning in order to provide technical training for the student through classroom and laboratory activity.

Some primary objectives and rationale for the Electronics program are the following:

- o Gain a knowledge of fundamental principles of electronics, computers, and programming, through the study of basic circuits, basic electronics, circuit analysis and design, use of laboratory test equipment in design and testing, computer programming in BASIC and assembly language, and the application of basic mathematical skills.
- o Attain the ability to use high level applied skills in a specialty area. This may be accomplished through minicomputer applications in real-time hardware control; consumer and industrial electronics applications; development and implementation of control system software; or module, PC board, or component manufacturing and testing. These applied skills help the graduate be productive almost immediately upon being hired.
- o Develop the capacity for future individual growth. Students must be prepared to continually update their training if they are to be prepared to cope with occupational desires and frustrations that only actual job experience can bring to light. They need specific skills to begin a job, yet enough breadth and flexibility in their educational background to permit reasonable latitude in the type of job assignments they can accept. The Electronics Engineering Technology Program stresses a broad in-depth understanding of basic fundamental principles in circuits, electronics, communication, digital circuits, and computer hardware and software, which gives the graduate a stable foundation to continue a program of self-education during future years.

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Electronics Engineering Technology enrollment has increased steadily during the past few years. Twenty-two seniors graduated during the 1981-1982 school year, and there are now 282 graduates in the field. Most are working directly in the area of their training.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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- C.7--OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS: ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS
- C.8--UNIVERSITY OF MICHIGAN
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- C.10--HENRY FORD COMMUNITY COLLEGE: ELECTRICAL-ELECTRONIC TECHNOLOGY PROGRAM, AUTOMATION/ROBOTICS OPTION
- C.11--WESTINGHOUSE DEFENSE AND ELECTRONICS SYSTEMS CENTER, BALTIMORE, MD
- C.12--TEXAS INSTRUMENTS
- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.4— CAD/CAM Operator Training Program,
Glendale, California**

This is an OTA Working Paper that has neither been reviewed nor
approved by the Technology Assessment Board

July 1984



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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:
CAD/CAM OPERATOR TRAINING PROGRAM, GLENDALE, CALIFORNIA

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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

CAD/CAM OPERATOR TRAINING PROGRAM

Glendale, California

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CAD/CAM OPERATOR TRAINING PROGRAM

Glendale, California

SUMMARY

The Glendale CAD/CAM* Operator Training Program was sparked by the spirit of innovation and cooperation on both the State and local levels. Funded by a combination of Federal and State monies and sponsored on the State level by two State agencies, the Glendale program is one of six pilot programs in California which bring together colleges, industries, and local government agencies to train California residents to work in emerging or expanding technological fields. The Glendale program, which trained participants with drafting backgrounds to utilize computer-aided design systems for mechanical design and printed circuit board detailing, was a cooperative venture between Glendale Community College, local industries, the City of Glendale, and other local organizations. At the end of the first cycle of the program, 7 of the initial 12 enrollees were employed as CAD/CAM operators and 3 others found related drafting jobs.** At this writing, the second cycle is still in session.

I. BACKGROUND

Coordinated Funding Project for New Vocational Education Programs.

The Coordinated Funding Project--administered under the joint sponsorship of the Chancellor's Office of California Community Colleges and the State's Employment Development Department (EDD)--is an innovative, State-level response to the need to develop vocational education programs in emerging and expanding technologies in a period of budget cuts and reduced resources for educational programs. The State-wide project was created in response to

* Computer Aided Design and Computer Aided Manufacturing.

** See p. 22 for a full accounting of placement results.

recommendations of a legislative "Task Group" set up in 1979 to review vocational education in California and to suggest how vocational education funds be utilized most effectively. In its final report, the Task Group made the following recommendations: 1) the adoption of State-level administrative policies to allow for the consolidation of resources,* 2) greater private sector involvement in vocational training, and 3) expansion of programs linking worksite training and classroom instruction.

The Coordinated Funding Project is a combined effort on the part of the Chancellor's Office and the EDD to consolidate State and Federal funds from three sources--the Comprehensive Education and Training Act (CETA),** the California Worksite Education and Training Act (CWETA), and the Vocational Education Act (VEA)--to support pilot education and training programs involving a high level of coordination between colleges, private industries, and (in some instances) local government bodies. In November 1981, the project staff sent Requests for Proposals (RFPs) to all of the community colleges in California asking for concept papers outlining innovative programs in emerging or expanding technologies or labor intensive occupations that combine classroom instruction with worksite training in order to 1) upgrade basic work skills, 2) provide entry-level training, or 3) enhance or build on the skills of displaced workers. The colleges were specifically requested to design programs for occupations not included in their current curricula and to seek new solutions for long-existing problems. Specific objectives to be met by each local program included the following:

- o To provide vocational training programs meeting specific local employers' needs;
- o To involve local employers and other appropriate entities in project planning, curriculum design, and training implementation;

* It was noted in the report that the existence of a "myriad of programs providing occupational training" had resulted in fragmentation of funding and administrative procedures and created a significant obstacle to effective coordination.

** See footnote on p. 8.

- o To provide effective job skills training to the project participants;
- o To obtain continuing employment with career advancement potential for project participants;
- o To incorporate the resulting curriculum into ongoing college vocational education programs.

Over 50 colleges responded to the RFP, and in January 1982, 4 individual colleges and 2 college consortia were awarded contracts totalling \$800,000 (for all six programs). The top-ranked proposal was a program submitted by Glendale Community College (GCC) to train CAD/CAM technicians. In February 1982, GCC was awarded \$84,271 to train 24 participants (12 in each of 2 training cycles*); shortly thereafter, five other schools or consortia of schools were awarded contracts to train participants in fields such as computer-aided drafting, computer-assisted machining, digital electronics and micro-processors, business machine and computer repair, and solar and alcohol technology and wood products manufacturing.

The remainder of this study focuses on the CAD/CAM technician program operated by Glendale Community College. In the Fall of 1982, a new State initiative, titled "Investment in People," set aside \$3,400,000 to fund other college programs of a similar nature to those supported by the Coordinated Funding Program. Glendale submitted an Investment in People proposal containing a modified and expanded version of its original CAD/CAM program and was awarded \$55,885 to train additional participants in various computer-aided design applications. The expansion of the Glendale CAD/CAM program under Investment in People funding is outlined on pp. 22-23.

* Each training cycle consisted of 12 weeks of formal classroom/laboratory instruction, followed by 200 hours of worksite training at the participating companies.

Glendale CAD/CAM Operator Training Program

The Glendale program is an attempt to demonstrate the feasibility of coordinating a variety of funding sources (CETA, CWETA, and VEA) as well as the efforts of a variety of participating organizations and agencies. The project is a joint effort on behalf of Glendale Community College, the Jet Propulsion Laboratory, Singer Librescope, Computervision, the City of Glendale, and the Glendale Private Industry Council. The remainder of this introductory section is devoted to brief descriptions of these participating organizations and the part each plays in the CAD/CAM program. Section II describes the project activities of each major player in greater detail.

Glendale Community College

Glendale Community College (GCC), designated as the training program operator, is fully accredited by the Western Association of Schools and Colleges as a 2-year institution providing both general and specialized education to youth and adults. Its four primary objectives are to 1) educate students to meet the lower division requirements of a university or 4-year college, 2) provide post-secondary vocational education for students preparing for entry-level positions and for employed students upgrading their skills for job advancement or to meet new job requirements, 3) post-secondary education for "personal improvement" (i.e., coursework taken to satisfy individual interests and which does not lead to a degree or certificate), and 4) adult education "below the lower division level," which includes coursework leading to the high school diploma, career and vocational classes, citizenship classes, and classes serving special interest needs of the community.

GCC was founded in 1927 and, until recently, was under the jurisdiction of the Glendale School Board, which was also responsible for the primary and secondary-level education system in the district. In the Fall of 1984, a new school board, solely responsible for the Glendale Community College District, was created. This action is especially significant in relation to the school's regular vocational education programs and to special projects like the CAD/CAM operators program in that the president/superintendent of the new school board has expressed a specific commitment to vocational education and is a member of the Glendale Private Industry Council (see below, pp. 7-9). Approximately half of the college's 10,200 students (5,200 full-time; 5,000

part-time) are either enrolled in technical or vocationally-oriented certificate or transfer programs* or take one or more vocational education courses.

The CAD/CAM Operators' Program was coordinated by the college's director of special programs and was taught by the senior drafting instructor.

Jet Propulsion Laboratory (JPL)

JPL was established by the California Institute of Technology (Cal Tech) as a private, non-profit research and development laboratory.** Located on the outskirts of Glendale in La Canada, California, JPL employs approximately 4,600 people: approximately 2,400 are engineers and scientists; 1,000 are support personnel; and 200 are engaged in manufacturing prototype products (see following paragraph). When the laboratory was founded in 1945, its major activity was to complete rocket research and development for the U. S. Army. In 1959, it became a NASA research center. Today, although its principal contract is still with NASA, JPL also has research and development contracts with the U.S. Department of Energy, the Department of Defense, the National Institutes of Health, some local agencies, and some private industries.

As a NASA contractor, the principal focus of the laboratory's activities is lunar and interplanetary investigation--tracking and acquiring data from satellites and probes in NASA's deep space network. Currently operating at a funding level of just over \$350 million, JPL concentrates on research, development, and design of products. Its manufacturing activity, therefore, is limited to the production of prototypes and is a proportionately small part of the lab's responsibilities. For this reason, JPL has little computer-aided production equipment; it does, however, have approximately 500 computers

* Certificate programs are primarily business or technical programs designed for students preparing to enter the job market upon completion of the program. Transfer programs are designed for students planning to continue their education at a 4-year institution.

** Cal Tech continues to manage JPL's contracts. According to a JPL section manager, the difference between the research conducted at Cal Tech's main campus in nearby Pasadena and that conducted by JPL is that JPL is product development-oriented whereas the research on the campus is primarily academic in nature.

(ranging from mainframes to micros) which are primarily used for computer-aided design and other computer-aided engineering applications such as analysis and simulation of engineering data.* According to JPL's Design and Mechanical Support Section manager, JPL's concentration on development, design, and "first article delivery" means that the laboratory uses computers and computer-aided systems primarily as analytical tools rather than as production tools. The current focus of the Design and Mechanical Support Section is to attempt to save money and other resources in the preliminary stages of manufacturing by infusing into the design process the ability to do simultaneous analysis, material selection, and selection of fabrication work in an attempt to create a product design that could be implemented without wasting material or having to reconfigure tooling in the manufacturing process.

JPL's Design and Mechanical Support Section participated in the Coordinated Funding Project partially because of its growing need for CAD/CAM operators since 1980, when the section installed its first Computer vision CAD/CAM system. According to the section manager, the introduction of computer-aided design into the section enabled it to bid on and complete more work in less time and also--because the design engineers' time is considered to be too valuable to do detail and documentation work on their designs--created a need for a new category of employee--"CAD/CAM operators" who are skilled in drafting and in the operation of computer-aided design systems.** Approximately two-thirds of the participants in the Coordinated Funding

* "Computer Aided Engineering (CAE)...includes those computer systems designed to facilitate Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Business Systems (CABS), the Interactive Computer Graphics (ICG), and all those other systems that facilitate the solution of engineering problems. It plays a key role in areas such as design, analysis, detailing, documentation, N/C programming, tooling, fabrication, assembly, quality control, testing, and all aspects of management of the data base relevant to the particular product under consideration." Glower, Donald D. and Lindon E. Saline, ed, A Response to Advancing Technologies (Washington, D. C., American Society for Engineering Education), 1982, p. 7.

** Previous to the installation of the Computer vision terminals, the section contracted drafting work to independent drafters or drafting firms. It is anticipated that the CAD systems and the new CAD/CAM operators will eventually replace the need for contract drafters.

Project receive "worksite training" at JPL--hands-on laboratory work on the Computervision terminals that both complements their classroom instruction at Glendale Community College and assists JPL engineers in the detailing and documentation of their designs. JPL has hired 5 trainees from the first cycle of the program and may hire some from the second phase.

Singer Librascope

The remaining third of the original 12 Coordinated Funding Project participants received worksite training at Singer Librascope, a division of the Singer Company engaged in the production of military equipment.

Like JPL, Singer Librascope required trained Computervision operators and looked on the Coordinated Funding Project as a means of acquiring employees trained to company specifications. While all of the trainees received the same classroom instruction at GCC, their worksite training at Singer Librascope and JPL differed. Those who completed their laboratory training at Singer Librascope were trained to work on printed circuit board (PCB) designs, while the JPL trainees worked on mechanical designs.*

Computervision

Computervision--for many years the largest producer of turnkey CAD/CAM systems--participated in the Coordinated Funding Project by providing free training for the GCC drafting instructor in its Los Angeles training center.** The classroom instruction provided to the trainees was an adaptation of four of Computervision's customer training courses. Computervision also assisted by providing reduced-price training documentation.

* The students themselves were given a choice of industry-site on the basis of their interest in either mechanical or PCB design.

** For more information on Computervision, see Case Study #12. Computervision also supplied free training to two high school teachers, who became CAD instructors in a high school training program developed at approximately the same time as the Coordinated Funding Project's CAD/CAM Operator Program. For information on the high school program, see the Appendix.

Glendale Private Industry Council and the City of Glendale

The Glendale Private Industry Council (PIC) was formed in 1979 under Title VII of the Comprehensive Employment and Training Act. Title VII, the Private Sector Initiative Program, was aimed at giving business and industry a major role in designing and implementing employment and training programs tailored to local private sector needs. Although the authority of business and industry representatives on a number of PICs across the country has been limited by the control of the local elected officials (designated as CETA Prime Sponsors) over PIC activities, the Glendale PIC has effected a viable working relationship between local government, education, and industry representatives.

In order to describe the role played by the PIC in the Coordinated Funding CAD/CAM Operator Program, it is first necessary to provide a few paragraphs of background material on the PIC itself and its relationship with its Prime Sponsor, the City of Glendale. The PIC's board is primarily composed of business and industry representatives but also has representation from local government and community groups, including the Glendale Unified School District, the Employment Development Department, and the Department of Social Services. In 1981, the PIC merged with the CETA Advisory Council (which was under the jurisdiction of the City of Glendale, in its role as CETA Prime Sponsor). The merger occurred at a time when a number of other PICs and Prime Sponsors in other localities were also consolidating councils; in some locations, the mergers were seen by one or the other of the groups as "take-over bids" and were accompanied by vituperation on both sides. In Glendale and in some other locations, the consolidation of councils was seen as a reinforcement of an already effective cooperative relationship. According to the present PIC director, the PIC and the city have yet to disagree on matters of program or policy, largely because there is general agreement that the PIC should act as the policymaking body while the city acts as the administrative body.

* The successor to CETA, the Jobs Training Partnership Act, retains the private industry councils created under CETA and expands their responsibility and authority. In order to be certified under the new Act--which requires a service delivery area with populations of 200,000 or more--the Glendale PIC consolidated its council with the nearby Burbank PIC in 1983.

Another factor that enhances the PIC's ability to function in a coordinated manner is that it has eliminated duplication of services by designating specific types of training delivery to specific groups in the Glendale area. Glendale Community College, for example, provides classroom instruction and skills training under contract to the PIC; another designated contractor is responsible for work experience for youth, for example, and yet another takes responsibility for in-school youth programs. PIC board members and staff believe that these measures have helped it to become the top ranked council in terms of job placement in the DOL region covering California, Nevada, and Arizona.

The PIC played two roles in the CAD/CAM Operators Program. Its formal role was to provide administrative services for the program, including contract compliance, recordkeeping, participant tracking and reporting, operational monitoring, and technical assistance. These services were formally subcontracted by Glendale Community College to the City of Glendale, which, as the administrative arm of the consolidated council, performs similar services for PIC-operated programs.

The other role played by the PIC was informal but crucial to every aspect of the program from conception to delivery. The Glendale PIC defines its responsibilities in a broader context than the actual operation of training programs for economically disadvantaged participants. According to both the PIC director and the chairman, the PIC must have a sense of--and be active in--the community as a whole in order to be effective in its formal function of delivering private sector training programs for the community's disadvantaged residents. The board and staff members, therefore, perceive their function to be that of facilitators, or brokers, who can act to bring together representatives from business, education, and government to create the kind of working partnership they believe is the intent of CETA, Title VII, and its successor, the Job Training Partnership Act. It was acting in its role as a facilitator that the PIC had its greatest impact on the CAD/CAM Operator Training Program. The proposal that won the Coordinated Funding Project contract for Glendale Community College was conceived by the PIC director and was an adaptation of a computer-aided design program for high school students proposed by the PIC chairman, who is also the manager of JPL's Design and Mechanical Support Section and a member of the Glendale Unified

School Board.* The college program expanded on the high school program, which was designed to familiarize high school students with CAD/CAM technology and to encourage them to continue their education in computer-aided technologies (see Appendix). The college program, on the other hand, was conceptualized as a means of serving the participating students and companies alike by training the students to fill immediate employment needs at JPL and Singer. Both programs were designed to serve their respective educational institutions by upgrading teachers, introducing new technological curricula, and providing courses that would eventually be incorporated into the ongoing curricula of both the college and the high school.

The CAD/CAM program, then, resulted from the synergistic relationship between the PIC, the college, and industries like the Jet Propulsion Laboratory. It derives also from the leadership of individuals like the JPL section manager whose activities in other arenas (as PIC chair and as School Board member) provided him with both the multiple perspective and the position to effect the coordination called for in the State's Coordinated Funding Proposal.

* Because the Glendale Coordinated Funding Project was not a PIC-sponsored program, the question of conflict-of-interest did not arise in relation to JPL's role. Conflict of interest is, however, a debated issue in the new Jobs Training Partnership Act. According to a report released by the National Governors' Association, "at least 15 states place total bans on designated officials from conducting business either with the State, or local municipalities, or other governmental entities of which they are members." Some private industry council members in some localities are, therefore, prohibited from allowing PIC training programs to be operated in or for their places of business. A number of private industry councils, on the other hand, operate on the principle that PIC board members can have the most impact by opening up their own businesses or industries to PIC programs, thereby providing training and employment opportunities to eligible participants and, at the same time, illustrating by example that such programs can be effective for employers. In the NGA report cited above--which specifically addresses the question of conflict-of-interest in regard to the new Job Training Partnership Act--the Georgia Employment and Training Council specifically recommends that "Federal regulations concerning conflicts-of-interest which are presently being drafted exempt PIC members from prohibitions against conducting business in their own or any other service delivery area where: 1) such member notifies in writing his potential conflict of interest to the council or administrative entity; 2) such member refrains from voting or in any way participating in the decision to award contracts; and 3) the council or administrative entity makes as a part of its record the reasons for awarding the contract to one of its PIC members and why the award is in the public's best interest." "Implementing the Job Training Partnership Act. Technical Brief: Conflict of Interest" National Governors' Association, December, 1982. Issue paper presented for response.

II. CAD/CAM OPERATOR TRAINING PROGRAM

Goals and Objectives

The overall goals of the CAD/CAM Operators' Program are 1) to develop a training program in CAD/CAM which could be incorporated into the community college system in Glendale, and which could be replicated at other community colleges, and 2) to train 24 participants to be CAD/CAM operators. Apart from those overall goals (which are primarily those of the college), the PIC, JPL, and Singer Librascope each had additional objectives for their project participation.

The Private Industry Council representatives viewed the Coordinated Funding Project as an opportunity to strengthen the bond between the college and local industries by demonstrating that the two entities could work together in a project that could benefit each while also helping the community by training and employing local residents. In particular, the PIC hoped to showcase the college as a resource for local industries which could, by assuming industrial training responsibilities, help the companies save on training expenses. The PIC also saw its participation in the project as a way to partake in an effort to build the community's capacity to engage in high technology training which--in the opinion of key staff and board members--may not be appropriate for the majority of CETA-eligible residents without the necessary background skills.* By helping the community to establish a high tech training capacity, the PIC hoped to establish a training resource which could eventually be used by economically disadvantaged participants whom the PIC would first provide with the prerequisite skills such as drafting.

Although the Jet Propulsion Laboratory and Singer Librascope had a major objective in common--that of obtaining employees specifically trained to their work requirements--the secondary objectives of the two employers differed. One basic difference was that Singer required students trained as detailers--

* Because the CETA funds used in the Coordinated Funding Project were discretionary linkages funds earmarked for project administrative expenses, the project operators were not bound to meet CETA selection criteria, although they were urged to include as many CETA-eligible participants as possible. (See Selection, pp. 14-16.)

that is, CAD/CAM operators who do detail work on designs created by others-- whereas JPL wanted trainees who would do some basic design work and eventually become full-fledged designers. Consequently, JPL informed all of the students who completed their worksite training at the laboratory that those who would be hired would be expected to continue their education (at company expense) at a four-year college. A further objective held by JPL was to build the college's capabilities so that the lab could draw on it as a training resource in the future. Computervision's object in participating in the project was to support its customers--JPL and Singer Librascope--by assisting in the instruction of their future employees and to assist the college by helping it to develop the capability to create an ongoing computer-aided design course utilizing Computervision equipment.

Planning and Development

The State-level planning for the Coordinated Funding Project and much of the local-level planning for the Glendale program have been outlined in Section I of this study. This section will, therefore, discuss the program development efforts that took place after the selection of Glendale as a contract recipient.

Previous to the writing of the proposal, both JPL and Singer Librascope had made commitments to participate in the program. Once the proposal was accepted, the PIC contacted Computervision and secured its commitment to provide training for the Glendale instructor. The school's engineering drafting instructor, who also works part-time at JPL as a senior engineer, was chosen as the CAD/CAM program instructor and was given the responsibility of designing the curriculum. To prepare for his curriculum-writing and instructional duties, the instructor attended a summer-long upgrading program: he began his training by completing a week-long Computervision self-study course at JPL, followed by a week of on-the-job training in JPL's CAD/CAM operations. During the following 9 weeks, he attended 100 hours of training at Computervision's Los Angeles training center, completing customer courses in mechanical design and electro-mechanical design. The week-long courses at Computervision were supplemented by on-the-job training at both Singer-Librascope and JPL. At the completion of his training, the instructor designed the classroom training curriculum for the program, aided by advice from JPL and Singer employees.

Because the students would be receiving classroom instruction at the college and laboratory training at one of the participating firms, much of the program development effort included setting up formal mechanisms for coordinating between JPL, Singer Librascope, the PIC, and the school. That coordination involved logistics planning. Discussions between the college and the two companies resulted in a plan whereby students would attend 3-hour lectures at the college two mornings a week and laboratory training two late afternoons or evenings a week (to avoid students competing with employees for workstations).

Administrative and Instructional Staff

As the primary program operator, Glendale Community College had fiscal responsibility for the project. It was also responsible for delivering the classroom and laboratory training and for appointing a program counselor to act as liaison between the students, the college, and the participating companies. The college's director of special projects for vocational education served as the overall program administrator. Administrative services were subcontracted to the City of Glendale/Private Industry Council, while the college retained the activities of recruitment, screening and selection, counseling, and placement. The college's engineering drafting instructor was responsible for delivering the classroom instruction, overseeing the laboratory instruction at JPL, and coordinating with the two companies. The instructor, a past graduate of Glendale Community College, has a bachelor's degree in industrial design from California State University at Los Angeles, a master's degree in industrial design from California State University at San Jose, and a vocational education teaching credential from the University of California at Berkeley. His previous industrial experience includes work at Columbia Broadcasting Corporation as a designer, at General Electric's Nuclear Engineering Division as a packaging engineer, and at IBM as a senior design engineer.

Facilities and Equipment

Classroom instruction was delivered at Glendale Community College, which has a fully equipped traditional drafting classroom but no computer-aided design stations. Eight of the initial class of 12 students attended the laboratory portion of their training at JPL, which has 4 Computervision terminals

dedicated to training purposes. The remaining students had their laboratory instruction at Singer Librascope, which has 4 Computervision terminals in its engineering department for use by program trainees and Singer employees alike.

Program Funding

Glendale Community College received \$84,271 from the Coordinated Funding Project (\$3,243 from CETA; \$19,533 from CWETA; and \$61,495 from VEA). The CETA funds and approximately half of the CWETA funds were subcontracted to the City of Glendale to cover administrative services, and the remainder of the CWETA funds paid for a portion of the instructor's retraining (4 weeks of on-the-job training at JPL and 4 weeks at Singer Librascope). The VEA funds were devoted primarily to covering the direct costs of the training for the 24 participants. In addition to the State funding, the participating firms provided the following in-kind contributions: 100 hours of computer-aided design training for the Glendale instructor (Computervision) and equipment-use-and-maintenance costs for the CAD/CAM terminals valued at \$97,200 (JPL and Singer Librascope). Glendale Community College contributed space and utilities totaling \$3,800.

Recruitment and Selection/Participant Profile

In May 1982 the college sent flyers announcing the CAD/CAM program to 2- and 4-year colleges and Employment Development Department in the Los Angeles County area. Applicants were required to be U. S. citizens; be 18 years old or over; have a high school diploma or general equivalency diploma; be able to pass a security clearance; and have completed the following college-level courses:

- o one semester of basic mechanical drafting
- o one semester of advanced mechanical drafting
- o one semester of descriptive geometry
- o or equivalent work experience.

Recommended but not required were the following:

- o one semester of electronic drafting
- o one semester of machine design
- o one semester of basic electronics or machine shop
- o prior work experience in the above areas
- o or equivalent work experience.

After making formal application for the program at the Glendale CETA office, the candidates took a written examination at the college on June 12. The applications contained questionnaires requesting information on the applicant's long- and short-term goals, attitude, and motivation. The formal examination contained practical drafting problems requiring a knowledge of tolerance, dimensioning, scaling, clearances, interferences, and electrical schematics. From the initial group of over 50 candidates, the college representatives selected 18 on the basis of both test scores and indications of practicality, willingness to do detailed work for long stretches of time, and motivation shown on the application questionnaires. Once the college made the initial selection, representatives from JPL and Singer interviewed the students and made the final selection.

The majority of the 12 students selected as program participants for the first session, which began September 13, had previous machine shop or drafting experience. Over half had 2-year drafting certificates, and 5 of those students also had 2-year certificates in electronics or machining. The average age of the group was 23. Two participants were female; one was Hispanic; four had incomes below the poverty level; one was a displaced homemaker; and four were veterans.

Similar selection and recruitment procedures were followed for the second group of 12 participants, who began the coursework in February, 1983. The second group was approximately 50 percent female and included 4 Hispanics and 3 Orientals.

Classroom Instruction and Laboratory Training

The students received 12 weeks of formal instruction (6 hours a week of classroom instruction and 6 hours of Computervision CADDS 3 terminal training per week). Because no terminals were available in the college classroom, the classroom instruction was strictly devoted to theory, which was then applied in practice in the company laboratories. The GCC instructor was responsible for classroom instruction and for monitoring the laboratory sessions at both JPL and Singer Librascope. Instructional materials consisted of four, Computervision training documents--CADDS 3 Pocket Reference, CADDS 3 Mechanical Basic Guide, CADDS 3 Mechanical Design Workbook, and the CADDS 3 Printed Circuit/Electrical Schematic Basic Guide*--and Computervision's self-study audio/print learning package, "Introduction to CADDS 3 Operation," which teaches the basic concepts and commands needed to use CADDS 3 applications software.

Curriculum

The curriculum was designed to include the introductory material covered in the self-study package plus three Computervision CADDS 3 customer courses: 1) Basic Mechanical Design, 2) Advanced Mechanical Design, and 3) Basic Printed Circuit/Electrical Schematic Design. The first week of class was devoted to an overview of CAD/CAM technology, during which time the instructor lectured on CAD/CAM system hardware and software, turnkey CAD/CAM systems, computer generated visualizations, computer-aided design and computer-aided manufacturing processes and applications, and the integration of CAD/CAM into industrial processes.

During the second week, students were introduced to the basic techniques for using CADDS 3 software, concentrating on terminology, log on/off procedures for entering and leaving the system, and basic command language. The lecture portions of the second week of study covered the format of command language

* CADDS is Computervision's "Computer-Aided Drafting and Design System." Students were required to purchase the pocket reference and the mechanical design workbook; the school supplied them with the two basic guides. (Computervision, which normally sells the basic guides for \$75 each, provided them to the college for \$30 each.)

syntax—made up of verb + noun + modifier strings which the operator uses to execute a command by inputting a function (verb), such as "insert," plus a geometric entity (noun), like "line," plus a modifier which describes the geometry, such as "parallel" or "perpendicular." The students also learned how to use the system's on-line documentation feature, which aids the operator by prompting him or her with information on, for example, what "nouns" (line, circle, arc, fillet) go with specific "verbs" (insert, delete, or combine, for instance) and what modifiers can be used with particular verb/noun combinations. During the laboratory sessions, the students completed portions of the Computervision audio cassette/workbook course under the instructor's supervision.

Following the basic operations segment, the students spent two weeks (24 hours) learning to use the system for basic mechanical design. This segment included the fundamentals of part creation (i.e., how to use the system to create lines, circles, arcs, and fillets) and part filing (how to file a drawing of a part in the system); how to erase, modify, and manipulate elements; and basic projections (how to reproduce objects on planes or curved surfaces by projecting their points to create 3-D objects).

During the following 2 weeks, the students learned how to insert dimensions in mechanical drawings (including linear, angular, radial, and diameter dimensions, dual dimensions, and extension lines and arrows); how to use construction aids, such as grids and layers; how to size and scale part-drawings; "zooming" (focusing in on a small section of the drawing on the screen or widening the focus to include the full drawing); and how to insert textual notes and symbols to accompany their drawings. The laboratory work during this segment consisted of working through specified sections of the CADDS 3 Mechanical Design Workbook and completing individual projects involving the creation of 2-D and 3-D parts.

The next 3 weeks (weeks 7-9 of the course) were devoted to printed circuit/electrical schematic (PC/ES) applications. The first lecture in this segment covered the differences between mechanical and PC/ES applications and operations. The students then learned to create electronic symbols (called

"nodal information" in Computervision terminology) and to digitize* and annotate electrical schematics, which the computer then converts into a "net list," i.e., a list of all the start- and end-points for specific wire paths on the board. By the eighth week, the students were creating PC component diagrams, digitizing simple PC boards, and then using the system to merge the printed circuit boards and to automatically route the result.** They then learned to edit their PC boards*** and to record the parts and computer files (i.e., to store both the PCB drawing and the schematic and net list information in the computer). As in the mechanical segment, the students were required to complete individual projects using the terminals in the laboratories.

During the next two weeks, the students worked on specific electro-mechanical design problems dealing with the design and packaging of printed circuit boards. The last week of the course was devoted to review and to the final examination.

* "Digitizers" are instrumented surfaces on which the location of a point, selected with an associated cursor unit, is automatically converted into digital, x-and-y coordinate data suitable for transmission to a computer (Turnkey CAD/CAM Computer Graphics, A Survey and Buyer's Guide, 3-17). In the PC/ES operation described above, "digitizing" means to use a stylus to locate points which will eventually be connected by wires on the finished circuit board.

** The "merge" process tells the system that all of the components that exist on the board must be hooked up, based on the net list, so that the information on the net list is actually merged into the printed circuit board design. In the "routing" process, the system automatically indicates to the operator the lines that physically connect the digitized points.

*** The editing process is necessary because the system cannot always route every wire on every board. For example, if the system cannot get from point A to point B without intersecting another point and so grounding-out the wires, the human operator must drill a hole in the board, run the wire along the bottom side, and drill back up to the component side so that he can continue to run the wire on an unobstructed path.

Instructional Methods

When he developed the curriculum, the instructor was faced with a problem intrinsic to the structure of the program: how to modify the Computervision courses, which were designed for students with 4-hour-a-day access to terminals, to be taught in the Glendale format (6 hours a week of classroom instruction; 6 hours a week of laboratory practice). A number of his teaching methods were therefore dictated by the peculiarities of the situation. A portion of the classroom time was devoted to lecture on and class discussion of the theory behind the laboratory work to be done in the following lab session. Because of the lack of equipment, the instructor used the chalkboard to demonstrate the basic principles, and the students completed pen-and-paper exercises simulating the terminal exercises they would perform in the laboratories. The remainder of the classroom time was spent in group discussions of individual problems encountered in the laboratories. (Although a number of the students were reticent about discussing those problems in a group situation, all students were required to do so in order to provide them with experience in communicating problems to co-workers and attempting to solve them in a group situation.) The instructor's object in this was to simulate the industrial environment to the greatest extent possible. Students were expected to produce professional-level work; were expected to meet strict deadlines for their twice-weekly lab work and for the projects required at the end of each section; and were trained to solve the sort of practical problems they would face on the job.

Students worked two-to-a-terminal in the laboratory sessions, using the "partner system" that Computervision trainers use in their customer classes. Each student would work on the terminal for approximately 15 minutes at a time, while his or her partner would monitor the operation to make sure it was being done correctly and would provide assistance when necessary. This system, according to Computervision, allows each partner to both observe and perform specific operations and therefore reinforces the learning process. Because JPL had four terminals located in a dedicated training lab and because the laboratory operates on a flexible schedule, the students who did their laboratory work at JPL had 4 to 6 extra hours a week of terminal time. According to the instructor, the students were all so highly motivated that they had to be forcibly ejected from the laboratory at 11:00 p.m.

In addition to the classroom and laboratory work, the instructor arranged for two field trips--one to the Computervision Training Center in Los Angeles, and one to Weber Aircraft to observe the IBM/CADAM system in a production environment.*

Examinations and College Credit

Students were given an examination at the end of each major course segment (basic operations, mechanical application, and electrical applications) and took a 3-part final examination covering mechanical design, electrical design, and basic drawing. All but one of the students passed the final test and received 3 units of college credit for the course.**

Student Evaluations

In written evaluations completed at the end of the classroom/lab portion of the program, the trainees gave both the instructor and the course high marks. Most, however, stated that the course would be improved by more terminal time and more time spent on printed circuit board design. (See Section III, pp. 31-32 for more recent evaluations of the course by session I trainees now working at JPL and Singer Librascope.)

Worksite Training

Once they completed the classroom/laboratory portion of the program, the 11 remaining students began worksite training at JPL and Singer Librascope. This portion of the training consisted of 200 hours of work, which in the case of the 8 JPL trainees, was divided into 10 20-hour weeks. Because Singer Librascope was anxious to place its trainees on the permanent payroll as soon as possible, the 200 hours of training for the 3 Singer participants was condensed into 7 weeks. Trainees in both locations worked on actual

* See Case Study #6 for a description of CADAM training in computer-aided design.

** The one student who did not pass the final exam was the only student who carried a full-time job while participating in the program. The combination of full-time work and program participation proved to be more than he could accommodate.

production designs and were paid salaries of \$5.00 per hour by the firms. (Customers were informed that the design or detail work was being performed by student trainees, and the savings--in terms of lower-than-average salaries paid during the training period--were passed on to the customers in form of decreased design-room costs.)

The Singer Librascope trainees spent the worksite training portion of the program primarily doing detailer work on printed circuit board (PCB) designs. This included digitizing PCB drawings to input the design into the computer, editing existing designs, creating detailed drawings from an existing data base, and creating photo tools. The students who completed their worksite training at JPL were given some design responsibilities as well as detail work. Their specific task was to work on mechanical designs for support equipment and peripheral structures, such as inspection platforms, for the Galileo spacecraft. Given a basic design created by a JPL engineer, it was the trainees' job to complete the design, making sure that it met both the design and manufacturing standards (part tolerance and material selection, for example) specified by the design engineer. In many instances, completing the engineer's design required the trainee to design a part or structure forming a portion of the total design. The design work done by the trainees, closely monitored during the worksite training period, is a significant aspect of the duties of those trainees who became permanent employees.

Related Services: Counseling, Placement, and Follow-up

Counseling, placement, and follow-up services were formally assigned to the college. The college's special projects department has a full-time counseling staff, one of whom was assigned part-time to the Coordinated Funding participants. In effect, however, most counseling was informal and was provided by the instructor and the Singer and JPL employees who oversaw the students at the laboratory sites. Although placement services were officially the responsibility of the college, PIC representatives aided GCC in placing those program graduates who were not hired by either of the participating firms. Follow-up procedures, planned for 30-, 60-, and 90-day intervals after program completion, were conducted by the college.

Results

Placement

Seven of the 11 trainees who completed both the classroom instruction and worksite training portions of the program were hired by either JPL or Singer Librascope. JPL's stated intention at the beginning of the program was to train 8 participants in its lab and to hire the 4 who were best qualified. The laboratory exceeded its original intention by hiring 5 trainees at the completion of the worksite training in February, 1983. The new JPL CAD/CAM operators received entry-level salaries of \$6.00-\$7.50 per hour. Two of the JPL trainees were placed in other firms in design and drafting jobs which do not, however, involve CAD/CAM operation.

Singer Librascope had originally intended to hire all three of the students who trained at the firm. One of the trainees, however, failed to pass the security clearance required for all Singer Librascope employees. That trainee has since been hired by Glendale Community College in a nontraining related capacity. The other two were hired by Singer in January, 1983, at starting salaries of \$6.25-\$7.25 an hour.

Singer hopes to hire 4 trainees from the second session of the program, which at this writing has not yet entered the worksite training stage. Whether or not JPL will be able to hire any of the second-session trainees will depend on the laboratory's need and funding situation at the end of the summer.

The Investment in People Project

One of the results of the CAD/CAM Operator Program was achieved well before the first group of participants completed their classroom instruction. In October, 1982, the State Community College Chancellor's Office and the EDD announced that additional funds for innovative college programs would be available under the Governor's Investment in People Initiative. Glendale Community College, again with the help of the PIC and the City of Glendale, submitted a proposal to expand the CAD/CAM Operators' Program to adapt it to a wider range of applications (including architectural, piping, and structural design); to recruit additional applicants and involve more local industry; and to provide further training for instructors from GCC to help the college expand its already developed CAD curriculum. In December, 1982, the college

was awarded Investment in People funding totaling \$55,885 to provide 10 weeks of combined classroom instruction at GCC and on-site laboratory work at the Electric Optic Systems Division of Xerox Corporation and Jacobs Engineering (an architectural and civil engineering firm).

Unlike the Coordinated Funding Project participants, 32 of the 40 Investment in People participants were company employees requiring upgrade training in computer-aided design. Because the Xerox Electro Optical Systems employees were to be trained for aerospace applications, a combined class serving the second session Coordinated Funding participants and the Xerox Investment in People participants was planned for the Winter-Spring semester of 1983. The Jacobs employees, who were to be trained in architectural applications, attended a separate course, taught by an employee of Jacobs certified by Glendale College. All of the industry employees received laboratory training at their respective companies. The eight trainees who were not company employees joined the Coordinated Funding participants at Singer and JPL.

Benefits

Aside from the obvious benefits to the trainees, the CAD/CAM Operator Training Program produced beneficial results for the sponsoring companies, agencies, and institutions. Both employers got CAD/CAM operators trained in their specific applications and operations for a fraction of the cost involved in company-operated training programs. Singer Librascope, which specifically seeks young, energetic drafters to be trained as detailers in computer-aided PCB applications, obtained young CAD operators whose laboratory training was closely monitored by company employees--thus providing the assurance that they were trained in a manner acceptable to the firm. Singer representatives also point to their participation in the selection of the trainees and the opportunity to observe them over an extended period of time as added benefits.

JPL representatives look on the training program as a first step in reducing the laboratory's dependence on the contract drafting houses that traditionally performed the manual drafting function now being replaced by CAD/CAM.

According to the manager of the Design and Mechanical Support Section, the section has been able to accommodate double its previous workload since the introduction of the CAD systems in 1981 and can accomplish much of the work done by the contract drafters with a smaller number of permanently employed

CAD/CAM operators. Furthermore, since the systems themselves are extremely accurate tools, JPL can increase productivity and lower its price structure by hiring trained CAD/CAM operators at entry level salaries and passing the savings along to its customers. An added benefit from JPL's point of view is the future potential of the trainees. All of those who were hired by JPL accepted their positions with the understanding that they will continue their education by pursuing 4-year engineering degrees and eventually become part of the engineering design staff in the section. In this way, JPL hopes to achieve a number of long term results: to prevent the CAD/CAM operators from becoming static; to "home grow" new engineers who will have a working knowledge of CAD/CAM operations and JPL requirements; and to keep a constant flow of new CAD/CAM operators coming into the laboratory by replacing the older operators who have moved up to engineering design positions.

Glandale Community College, by obtaining the Coordinated Funding and Investment in People grants, now has increased credibility at the state level, which may, in turn, help the school to obtain additional funding for further innovative programs. Of equal importance is the CAD/CAM experience gained by the drafting instructor during his summer-long upgrading program, which was reinforced by his delivery of the academic year program. In addition, the college got the opportunity to integrate computer-aided design into its regular drafting curriculum--an opportunity that would have been greatly delayed had GCC been forced to wait until it could obtain its own equipment. (See pp. 32-35 for a discussion of the long-term potential of the CAD/CAM course at the college.)

Benefits to the Private Industry Council and Computervision were less tangible, but were, nevertheless, significant. By acting as the broker bringing the major players together and developing the operating systems that helped the program to succeed, the PIC demonstrated that it could fill the needs of the community at large while, at the same time, setting the stage for a PIC-funded program preparing disadvantaged residents to become drafters who could then take advantage of training programs concentrating on CAD/CAM skills. The program also aided the Private Industry Council by reinforcing the PIC-built bridges between the college and local industries and by demonstrating the PIC philosophy in action, i.e., that industrial commitment and academic training resources can be combined to benefit industries.

schools, and potential employees. Computervision, by participating in a program sponsored by JPL and Singer, demonstrated its willingness to support its customers in an innovative endeavor while also helping to provide those customers with trained Computervision operators.

Problems/Solutions*

The necessity of condensing the Computervision courses to fit the time frame of the college semester and the need to separate the classroom and laboratory segments presented ongoing problems. Although the Glendale students did have 12 weeks to complete 4 1-week Computervision courses, students who attend courses at one of Computervision's customer training centers engage in intensive 8-hour-a-day classroom and laboratory work. In the case of the mechanical design and printed circuit courses, the Glendale students received almost as much terminal time as a regular Computervision customer; but in the case of the Introduction to CADDS 3 Operation course, the coverage was reduced from approximately 40 hours to 10. It should also be noted that Computervision recommends that its customers' employees have from 60 hours of terminal time (for detailers) to 120 hours (for designers) after they take the Basic Mechanical Design course to thoroughly familiarize them with the system before they proceed to Advanced Mechanical Design. This, of course, was impossible for the Glendale students, who, because of time constraints imposed by the 12-week semester, had to proceed directly from the basic to the advanced course.

While the first group of students did not feel that the classroom/laboratory schedule was inconvenient, the students who are attending the second cycle of the course do have a problem in that regard. Those who do their laboratory work at Singer Librascope must attend labs from 11:00 p.m. to 2:00 a.m. because the systems are in constant use for production purposes during the first two shifts. This presents obvious difficulties for the second cycle students but alleviates the problem noted by Singer employees during the first cycle of the program, when regular employees were occasionally forced to work

* This section deals only with those problems directly related to the operation of the CAD/CAM Operator Training Program. Long-range problems that may arise in the future are discussed in the Evaluation section.

overtime in order to make up for the periods during which the terminals were used for training purposes. A similar problem was mentioned by some JPL employees, who had been accustomed to use the terminals "dedicated" to training for production design work.

A final problem related to the course structure is that the instructor occasionally had difficulty filling the mandatory 6 hours a week of lecture time with constructive material. While the chalkboard demonstrations of terminal operations and the pen-and-paper exercises were helpful to some extent, the instructor now feels that 4 hours a week of lecture and 8 hours of terminal time would be more appropriate for a course of this type.

While the instructor found ways to address some of the above-mentioned problems in the second cycle of the program, others were less amenable to immediate solution. The 10 hours originally devoted to the basic operations segment has been expanded to 20 hours. To deal with the problem of excessive classroom time, the instructor has assigned a term project for the second cycle of trainees. As part of the project, students will write papers dealing with the advantages and disadvantages of various CAD/CAM systems for specific types of design work, such as mechanical, printed circuit board, architectural and piping. Each student is assigned an in-depth research project on a specific system for a specific type of application, and the instructor has arranged for more field trips to enable the students to see different systems in operation. At the end of the course, the students will make class presentations on the results of their research, so that the entire class will have some familiarity with a wide variety of systems and applications. Because both cycles of the course were firmly locked in to the college's schedule by the time the difficulties associated with the classroom/laboratory ratio became apparent, it was not possible to make the adjustment to the 4-hour lecture/8-hour lab format which the instructor believes would be the best long-term solution to this problem.

The lack of adequate periods of time for terminal practice between the basic and advanced mechanical design segments is a problem which as yet has no solution in a course which is structured to fit into an academic semester. Even if the college had a well-equipped laboratory dedicated to training, it is unlikely that the students could have logged in 60-120 hours of terminal time to fully acquaint themselves with the system before proceeding from the

basic to the advanced segments of the course. It should be noted, however, that the students did have the opportunity to work on the terminals for at least 20 hours a week during the worksite training portion of the program. Therefore, although they may not have been able to make use of the terminals at the optimum period in the learning process, they did have up to 200 hours of experience on the terminals in addition to the time spent in the laboratory sections of the formal course.

A final problem, one noted by Singer representatives and by the Glendale instructor himself, is that--while the summer-long upgrading course provided the instructor with a grounding in the Computervision courses he adapted for his own course and a familiarity with the work of the Singer and JPL departments the students would be working in--his training was "barely adequate" to the task of training the students in advanced techniques. The major difficulty here was not with the abilities of the instructor, who had years of experience as an industrial designer and a drafting teacher and is familiar with the operation of another CAD/CAM system. However, while he was evaluated by both Singer and JPL representatives to be fully competent in his field and an excellent teacher, he did not have enough "system time" on Computervision terminals to become thoroughly familiar with all of the operations required for both mechanical and PCB design. This problem has decreased as the instructor has had more opportunity to work on the system himself and to observe the types of difficulties his students run into on the terminals, and it can reasonably be expected to be overcome entirely with time and experience. Because JPL and Singer designers were always on hand to aid the students with difficult problems, the students did not suffer because of the instructor's lack of extensive production experience on the system.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY

In spite of the problems noted in the previous sections, the CAD/CAM Operator Training Program can be rated as an overall success. The two employers have gained trained employees who fill what they both term as a "void" in their occupational structure, and both Singer and JPL pronounce themselves to be very pleased with the program graduates they have hired. The majority of the other graduates have obtained jobs; the college has gained experience in

teaching a CAD/CAM course and hopes to be able to integrate it into its regular curriculum; and the Private Industry Council has strengthened its position as a "broker" between industry, academia, and those in need of training and jobs. Many of the problems cited, in fact, are normal "start-up" problems associated with the initial implementation of demonstration programs with limited development time-frames. The other problems--specifically those involved in coordinating the resources and schedules of the industries, on the one hand, and the college, on the other--are currently being addressed by the PIC and the college and require both long-range planning and flexible short-term adjustments to achieve a workable solution (see below, p. 33).

Perhaps more important than the program's success in meeting its stated goals, however, is its value in demonstrating that industries and educational institutions can work together to meet their individual needs and the needs of the community with mutually satisfactory results. The present and future potential for the cooperative endeavor in high technology training initiated by the college CAD/CAM program and its sister high school program, along with student and employer evaluations of the first cycle of the college program, are discussed in the following paragraphs.

Employer Evaluations

Many of the employers' reactions to the program and to the students have been touched on in previous sections of this study. This section summarizes and draws together the overall response of the two employers who participated as major sponsors of the program.

Singer Librascope

Singer representatives interviewed--the manager of Engineering and Planning, the supervisor of the Computer-Aided Design Department who oversaw the laboratory portion of the formal course and the worksite training, and a PCB designer who worked closely with the students during the worksite training--all believe that the trainees did "a great job" and are fully satisfied with the work and motivation of the two trainees who were eventually hired. Even though the third trainee could not be hired for security reasons, the Singer employees said that he, too, did "very good work" and that they would have hired him had he been able to pass the security clearance. The supervisor of

computer-aided design was extremely direct in both his praise and his criticism of various aspects of the program. The problem created for Singer in the case of the trainee who was unable to get a security clearance, he felt, could have been avoided if more time and effort had gone into the initial screening process. The classroom training, in his opinion, was "adequate" but could have been "more adequate" if the Glendale instructor had received a longer training course himself. His final criticism of the program was that, while the trainees got a good "basic taste" of CADD 3 techniques, the instruction would have served Singer's purposes better had it been "more focused" on printed circuit board design. On the other hand, he recognized the instructor's problem of having students who would eventually be working in two different applications (mechanical and PCB) in the same class and believes that some grounding in mechanical design techniques is necessary for PCB detailers. Overcoming all of his criticism of the program, however, was the fact that the two trainees who were hired were, first of all, precisely the type of employees he was seeking (young, intelligent, and highly motivated) and, secondly, were tailor-trained to meet Singer's specifications. The program was especially valuable from Singer's point of view in that it trained students who had drafting experience but who did not have previous computer-aided design experience; they therefore did not have to "unlearn improper or unprofessional techniques" or techniques specific to another industry or another CAD/CAM system. Six of the trainees in the second cycle of the program are now receiving laboratory training at Singer Librascope, and the CAD supervisor hopes to hire 4 of them.

JPL

Representatives interviewed included the manager of the Design and Mechanical Support Section and the Technical Group Supervisor for Computer-Aided Design. Because the CAD/CAM Operator Training Program was conceived and fostered by the PIC (which is chaired by the JPL section manager), JPL's evaluation may be partially perceived as a parent's report of his child's progress. On the other hand, the section manager, being very much a businessman as well as a scientist, is committed to seeing a return on his investment in the trainees and to hiring employees whose work meets the standards of precision required in the aerospace industry. Another factor to be considered in JPL's evaluation is its philosophy of community participation

and its approach to employee training. The Jet Propulsion Laboratory is the largest employer in the Glendale area, and its managerial employees have implemented their sense of commitment to the community by serving on the Board of Education, educational task forces, and organizations like the Private Industry Council. JPL's participation in the CAD/CAM training program, therefore, was motivated not only by its need for trained operators but also by its desire to increase the college's focus on high technology training so that the school could better serve the needs of both the industrial community and the residents of Glendale. Integral to this approach is the notion that industry should communicate its perspective to educational institutions and work with them to address educational needs.* Aside from attempting to strengthen industry-education linkages in the community at large, the Design and Mechanical Support Section manager has institutionalized upgrade training for all of the employees in his section. Forty hours a year of upgrade training for each employee is built into the cost structure of the section, and completion of that training is an important factor in each employee's yearly appraisal. This procedure, which is in essence a mandate that every employee continually upgrade his or her skills, was instituted at approximately the same time that the CAD/CAM equipment was installed in the section and grows out of the manager's perception of the need for engineers and support personnel to keep up with the dynamic advances of the computer-aided tools of their profession.

The JPL representatives who participated in the selection of the trainees for the CAD/CAM Operator program therefore looked for applicants who were highly motivated and indicated a desire to continue their education; and the 5 trainees hired by JPL were those whose motivation both to work at the lab and to continue their education was the most apparent. As noted previously, JPL sought trainees who would eventually become fully-fledged design engineers--whom the training would provide with sophisticated entry-level skills and who had potential for career growth. When interviewed halfway through the worksite training period, JPL representatives were well satisfied with the work, the motivation, and the potential for success of all eight trainees. At

* JPL, which is an outgrowth of an educational institution but which operates like an industry, is perhaps uniquely structured to create the academic-industry linkages illustrated by the CAD/CAM program.

the end of the worksite training, the 5 trainees with the strongest desire to pursue engineering degrees were hired. Two months after they were hired as full-time employees, they are, according to the section's CAD supervisor, "doing very well" and continue to be enthusiastic and motivated. Ten trainees in the second cycle are now receiving laboratory training at JPL (8 from the Coordinated Funding Project and 2 funded by Investment in People).

Student Evaluations

Individual interviews were held with 5 Session I graduates--the 2 graduates hired by Singer Librascope and 3 of those hired by JPL. The students were uniformly positive about the instructor, appreciative of the experience they had received, and enthusiastic about the current work. All of the students gave the instructor an excellent rating, and some added that he was one of the best teachers they had ever worked with. They specifically noted his ability to provide clear and concise explanations; his attention to detail; his willingness to provide personalized assistance; and his patience and dedication.

While all of the students rated the course content highly, the new Singer hires would have preferred more class- and laboratory-time devoted to printed circuit board design. The other problem--one mentioned by the instructor himself and all of the students interviewed--was the ratio of classroom to laboratory time. While most of the students found the 6 hours of lecture per week helpful in the beginning of the course, all stated that more lab and less lecture would have been more appropriate during the second half. Two students noted that the small size of the class resulted in specific benefits: personalized instruction and an environment that encouraged the students to help each other to explore a variety of design techniques. Others mentioned that the instructional material, especially the Computervision workbook, were excellent and that the class projects were especially helpful as learning experiences.

Although many of the students were required to travel long distances--both to the college from their homes and between the college and the laboratory sites--only one mentioned traveling as a problem. None of the students felt that the time-lag between the classroom lectures and the laboratory practice sessions created undue difficulties. All of the graduates stated that the

laboratory experience was the most beneficial aspect of the program--not because the lectures were not good, but because of the necessity to engage in hands-on practice on the equipment. Two of the JPL students specifically mentioned the helpfulness of JPL employees during the laboratory sessions. When, however, the students were asked if they preferred the college-classroom/industry-lab-site set-up to a situation in which the lectures and laboratory work could have been centralized in one location, all but one said that it would have been preferable had the equipment been located at the college. The dissenting student (one of the few who had not had previous industrial experience) said that the industrial environment provided him with a greater incentive to work harder and learn more than would have been possible in a classroom environment. All of the students, on the other hand, felt that the 7-10 weeks of worksite experience after the formal coursework was extremely valuable, primarily because they were given "real" work rather than make-work and because it gave them an opportunity to learn about the specific working procedures of the two industrial laboratories.

All of the students expressed their intention of continuing their education at 4-year colleges or universities. One plans to pursue a mechanical engineering degree, and the others intend to work on degrees in industrial design.

Present and Future CAD/CAM Training Capacity of Glendale Community College

At the completion of the first cycle of the CAD/CAM program, Glendale College, as the program operator, had met the majority of the objectives set out by the Coordinated Funding sponsors. The college, with the help of the PIC and the sponsoring companies, had operated a vocational training program that met the needs of specific local employers; had involved the employers and "other appropriate entities" (the PIC and Computervision) in planning, design, and implementation; and had provided effective job skills training and continuing employment with career advancement potential to the participants. The final objective of the Coordinated Funding Project--to incorporate the resulting curriculum into ongoing college vocational education programs--has proved to be more difficult to accomplish than the other project goals.

Operating a program combining classroom and worksite training produced a number of beneficial results, not the least of which were the availability of state-of-the-art equipment at the industry sites and the opportunity given to

the trainees to acclimate themselves to an industrial environment. The use of industrial labs and the instructor upgrade training provided by project funds enabled the college to demonstrate its effectiveness in training vocational education students to meet industrial needs. The expansion of the program under Investment in People funding also demonstrated that the college could serve as a resource for training existing industrial employees as well as entry-level candidates. The college, however, is painfully aware of the possible "self-destructing" nature of a CAD/CAM program operated by a school with no equipment of its own. By the end of the second cycle of the program, both Singer Librascope and JPL will be "saturated" with CAD/CAM operators, at least for the present. In order to keep the program running, then, and to truly incorporate it into the ongoing curriculum of the college, CCU will have to find other sources of equipment. This potential problem was apparent from the inception of the program, and both the PIC and the college's director for special projects have been actively working on a solution. College representatives believe that the least promising solution in the long run is to assume that they will be able to perpetuate the program indefinitely by relying completely on industry laboratories for the hands-on portion of the training. They are, consequently, exploring the possibility of obtaining donated or reduced-price equipment to be installed at the college to be used for the training of regularly enrolled drafting and design students and for operating upgrade programs for industry.*

Technical Training Center

Another possibility, one which now looks extremely promising, is the creation of a centrally located technical training center, supported by local industries, schools, and agencies and outfitted with equipment to address a wide variety of "high tech" skills including CAD/CAM, computer repair, and word processing. The center—which until recently was little more than an

* In mid-May 1983 the college made the decision to continue the CAD/CAM training program through June 1984, funded with regular district funds. The lecture portion will remain at the college. The lab work will be conducted in the private sector at late night and early morning hours. In addition, the college administration is now developing a foundation which will be able to borrow money to be used, in part, to build new laboratories to house the equipment and to cover equipment maintenance costs.

Idea conceived of by the chairman of the Private Industry Council--is now beginning to look like it may become a reality. A recently closed junior high school in Glendale would provide the site; education and business leaders and local government officials have informally agreed on the concept; and a major producer of CAD/CAM equipment has expressed interest in the possibility of donating equipment. The current thought is that the facilities would be shared by all of the schools in the district and would operate on a three-shift schedule, allowing for three 3-1/2 hour teaching units in each subject per day. Although such a center would be challenging to administer and maintain, and although students would still have to travel to laboratory sessions, the problems noted previously with regard to coordinating production and training use of industry equipment would be solved, and the college would have access to the equipment it needs to continue its CAD/CAM course and to expand into related areas.

Future Potential

Glendale College vocational education instructors and administrators believe that a crucial element in the college's future potential to operate vocational education programs is the maintenance and expansion of the communication channel with local industries established through such means as the school's association with the PIC and through the Coordinated Funding and Investment in People projects. The open channel to industry representatives is seen as necessary for a variety of reasons. Glendale representatives believe that colleges are 5 to 10 years behind industry in technical expertise and sophistication of equipment; and they look on industry as a resource for instructor upgrading, information about new industrial advances and hiring requirements, and material and equipment to implement new courses. The college drafting instructor, for example, believes that within the next few years, mechanical and architectural drafting programs that do not incorporate computer-aided design will not be achieving their major goal, which is to produce job-ready graduates. In return for industry support, the vocational education division of the college is committed to institute whatever ongoing changes are reasonable and necessary to meet industrial needs and to serve as a training resource for local industries.

Although the college's present capacity to teach programs in computer-aided design and manufacturing is limited by its almost complete lack of equipment, the bridge-building activities of the past 4 years (participation in PIC programs and representation on the PIC board, recruitment of industrial representatives for college advisory committees, and participation in programs like the Coordinated Funding Project) seem destined to bear fruit in the near future. Local industries that have benefitted from CETA training programs operated by the college now donate material, equipment, and funds. The success of the Coordinated Funding Project demonstrated the college's ability and may bring more industrial support, open more industrial labs, and help the school to win more State funds. The Investment in People grant, which allowed the school to expand the CAD/CAM Operator program, is but one example of the college's potential to build on the achievements gained through working with local industries and agencies. More recently, the college was chosen as one of the possible West Coast sites for the General Motors/United Auto Workers retraining projects. The program proposed by GCC--a year-long electronics technician course--has been accepted in concept and will be implemented if it proves feasible for 20 laid off GM workers to either relocate to or travel to Glendale for the length of time it would take to complete the course.

The synergistic relationship between the college, the Private Industry Council, and the City of Glendale is a major key to the college's future potential. The PIC has engaged the support of its board members to aid the college in obtaining equipment. This, in itself, becomes a very powerful resource because of the stature of the industries--including JPL, ITT, Pacific Telephone, and banking and financial organizations--represented on the PIC board. Whether the final result of the effort to build GCC's equipment and laboratory resources takes the shape of a training center to which the college has access to or laboratories located on the college campus, the partners in the school-city-PIC relationship seem committed to making use of whatever equipment is obtained to serve the broadest possible constituency.

The Glendale Private Industry Council

While the formal role played by the PIC in the operation of the CAD/CAM Operator program was relatively minor, the importance of the Private Industry Council as an informal broker between educational, industrial, and

governmental organizations cannot be overestimated. The idea for the CAD/CAM Operator program originated with the PIC director and chairman; the PIC chair secured the cooperation of his own organization (JPL); the PIC director enlisted Singer Librascope and Computervision; and the PIC staff assisted in placing the cycle I graduates who were not hired by the participating firms.

Although the PIC's formal mandate is to operate training programs for structurally unemployed and displaced workers, the philosophy of the Glendale council encompasses a much wider sphere of activity than the direct operation of government-funded training and employment programs. Integral to that philosophy is the creation of linkages between the industrial and educational committees to enhance the activities and resources of each and to serve the community as a whole. In light of this philosophy, the role of the broker is profound, especially when one considers the difficulty of creating matches between the two ends of the labor market spectrum: on one end, technologically-oriented industries requiring many workers to have ever-more sophisticated entry-level skills; and, on the other end, the structurally unemployed,* who may have few workplace skills, and displaced workers, who may be only semi-skilled. Occupying the vast middle ground are colleges and high schools requiring assistance to update their curricula and upgrade their instructors so they can assist in the job training process; workers with outdated skills who do not meet the Federal poverty guidelines and are therefore ineligible for Federally-funded programs; and firms whose workers require upgrade training but which may not have the resources to provide that training in-house. By taking the broad approach and making the most of its formal and informal channels of communication between all of the sectors of the community, the PIC hopes to have a pervasive effect which, in the long run, may create that match between industry's high tech needs and the structurally unemployed.

At present, the PIC is working on a number of fronts, which, when brought together, may enable it to serve the needs of high tech industries and the structurally unemployed at the same time. Although the CAD/CAM operator

* Structurally unemployed individuals are those whose situation is independent of economic conditions, in contrast to the "cyclically unemployed" who are periodically without work due to specific changes in the general economy.

program did not serve the structurally unemployed, it did serve some displaced workers and some who were below the poverty level. It also strengthened college's training capacity and aided local industries. In addition, the CAD/CAM program demonstrated the feasibility of bringing the various participants together to create a successful high technology training program and set the mechanism in place for expanding it.

The concurrently operating high school CAD/CAM program described in the Appendix illustrates Glendale's capacity for serving another level of potential worker--the high school student who will eventually enter the market place and who could move from the CAD/CAM familiarization program offered by the high school to the Glendale Community College program or to a 4-year engineering program. Now that the feasibility for high tech training has been demonstrated and many of the mechanisms are in place, the PIC is considering the use of its own funds for a program that would provide the structurally unemployed with fundamental drafting and design skills and a basic familiarization with computer-aided design in order to prepare them for more advanced programs like the one now operating at GCC.

This type of activity--working both formally and informally to strengthen various segments of the education and training system and concentrating on strengthening the links between the segments--illustrates another tenet of the Glendale PIC philosophy, characterized by the following statement by the PIC chair: "There's a need to recognize that nothing is static--once you get into it, you've got to be willing to move. The way we've done that is to address needs that are peculiar and particular to industry now, and we ask industry to forecast needs downstream, so we can be ready to alter our training programs to be ready at the time that the need exists. My impression is that industry loves it if they're included and that school systems are now put in the position of preparing students for the real world. They're beginning to realize that they're both part of it and that the responsibility is a shared one." To further strengthen education's knowledge of industry, the PIC is working to encourage local schools to substitute a work experience program for the traditional sabbatical leave for instructors and to provide appropriate promotion credits for such a program. To increase industry's recognition of the capacities of educational institutions, the PIC encourages companies to look on vocational education teachers as a training resource and to contract

out in-house training to the colleges.* This system, according to the PIC chair, would cost the companies less than in-house training and would strengthen the schools' capacity to provide industrial-level technical training. While this notion would not necessarily work for all types of training in all companies, it is likely to work in a number of instances if well managed and properly designed.

The CAD/CAM Operator program illustrates that industry-education cooperative training endeavors can succeed, in spite of the difficulties that inevitably occur. The problem now facing Glendale Community College--how to continue the course when the two industrial sponsors are saturated and the equipment question is still up in the air--graphically illustrates the PIC chair's statement that "nothing is static." The PIC and the college, however, are ready to move--either to move to other companies to keep the program running until a permanent solution can be found, or to acquire equipment or establish a training center. This type of innovative approach to CAD/CAM training, which relies on mutual cooperation while recognizing that circumstances change and resources are limited, may not be guaranteed of certain success, but it is most certainly well worth the attempt.

* In many cases, this would involve providing industrial upgrade training to the teachers, as was done in the case of the GCC instructor.

APPENDIX

COMPUTER ASSISTED DRAFTING AND DESIGN PROGRAM
FOR HIGH SCHOOL STUDENTS

The high school program in Computer Assisted Drafting and Design (CADDs) was initiated by the chairman of the Private Industry Council, who also sits on the Board of Trustees of the Glendale Unified School District. The course was designed to be one of the regular Regional Occupational Program (ROP) courses offered by the Glendale Unified School District.* As the planning and design of the course got underway, however, it took on the nature of a community project. In addition to the ROP office and the school district, JPL, the Private Industry Council, and Computervision became involved in the preparation and implementation of the program. The Private Industry Council absorbed the cost of training two high school teachers at Computervision's Los Angeles Training Center, and JPL hired the teachers for a 10-week period to provide them with hands-on training prior to their teaching the course.

The major goals of the project were to familiarize 10 high school drafting students with computer-aided design techniques and operations; to provide upgrade training to the teachers; and to incorporate the course into the school district's ongoing curriculum. Along with customer training courses at the Computervision training center, the two teachers received on-the-job training at JPL in the Spring and Summer of 1982.

When the school year began in September, 10 students were selected on the basis of aptitude and interest to attend 4 hours a week of classroom instruction at the high schools and 2 hours a week of laboratory training at JPL. The year-long course covered basic terminal operations and the techniques covered in Computervision's Basic Mechanical Design Course (see

* ROP classes are offered in all of the school districts in Los Angeles County and are sponsored jointly by the Office of the Los Angeles County Superintendent of Schools and the individual school districts. ROP's objective is to establish occupational training programs that do not replicate or supplant the program efforts of other local education agencies and that make maximum use of public and private resources. ROP participants include public and private high school students, out-of-school youths, and adults residing in participating school districts.

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p. 17). In January, 1983, the school district was able to purchase two Apple microcomputers with software that simulates a number of the functions of the Computervision systems at JPL, so that the students are now able to get more hands-on practice during their classroom time.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

MANUFACTURING ENGINEERING APPLICATIONS CENTER (MEAC)

Worcester, MA

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MANUFACTURING ENGINEERING APPLICATIONS CENTER (MEAC)

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INTRODUCTION

The Manufacturing Engineering Applications Center (MEAC) was established in January, 1981, as a joint venture between Worcester Polytechnic Institute (WPI) and Emhart Corporation, a \$1.7 billion multinational manufacturing company headquartered in Farmington, Connecticut.

It is currently fashionable to overuse the terms "innovative" and "unique." When applied to MEAC, however, they are fully justified in their dictionary meanings. During its first two experimental years of operation, MEAC brought Emhart engineers and executives and WPI staff and students together to work on the practical application problems involved in introducing programmable automation systems to Emhart's operating divisions. WPI undergraduate and graduate students were given the opportunity -- and the responsibility -- of participating in the development of industrial robotic systems, three of which are now functioning in Emhart shops. To enable company employees to work in an environment free of the pressures of production and to provide the WPI participants with free access to the robots and other equipment they required to develop the systems, Emhart purchased the initial two robotic systems and transferred all of the necessary machinery to the WPI campus. Both Emhart engineers and union workers were given the opportunity to work an average of 3 days every week at the MEAC laboratory on the WPI campus, which -- by freeing them from the pressure and constant interruptions of the production environment -- enabled them to concentrate

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completely on the application problems at hand. The two pilot projects, a fastener tool testing system utilizing a PUMA robot, and a materials handling system built around a Unimate 2015F, were both completed within a 6-month time frame. From the company's perspective, the key to the cooperative endeavor was the project direction supplied by the Emhart engineer who took up residence at MEAC to keep the projects on track and on time. WPI, which has now expanded MEAC's base by opening it up to other companies, has incorporated Emhart's perspective by making on-campus project management by company engineers a requirement for present and future industrial participants.

Boiled down to the simplest terms, MEAC's success evolved from the fortunate circumstance of the right school joining hands with the right company at the right time. That is not to imply that Emhart and WPI found each other accidentally -- Emhart, in fact, proposed the MEAC project to WPI after investigating a number of engineering schools in the New England area. Nor does it imply that the first two years of experimental projects were free of conflicts, misunderstandings, and occasionally painful adjustments on both sides. The fortunate aspect, according to company representatives, is that what seemed, in theory, to be a "good fit" in the beginning of the partnership proved, in actuality, to produce even more benefits for both partners than originally anticipated.

Section I of this report provides background information on both WPI and Emhart, focusing on the individual characteristics of both the company and the school that make their ongoing partnership fruitful. Because Worcester Polytechnic Institute is "unique" and "innovative" in its own right, an extensive description of what is now known as the "WPI Plan" is included as an appendix to this study. Section II covers the establishment of MEAC and its

ongoing activities; and Section III discusses the future potential of MEAC, in particular, and WPI, in general, to continue to meet CAD/CAM education needs.

I. CORPORATE AND INSTITUTIONAL BACKGROUND

Emhart Corporation

The Emhart Corporation employs more than 29,000 people in some 96 principal operating facilities in 18 States and 15 countries abroad. Emhart's products are grouped under four business segments: Commercial products (door hardware, alarm systems, central keying systems); Components (blind rivets, fastening systems, metallic eyelets, specialty fasteners, liquid film, web and hot melt adhesive systems, special finishes and coatings, and such electronic and electrical products as capacitors, timers, audible signal devices, and solid state control systems); Footwear products (shoe machinery and machinery for materials processing and materials such as innersoles used in manufacturing shoes) and Industrial products (glass container making machinery, forehearths, refractories, rubber and plastic machinery, packaging machinery, gear manufacturing machinery, and electronic component assembling systems).

In spite of its size and its rank in the Fortune 500 (201 in 1982, up from 215 in 1981),¹ Emhart's production methods were primarily conventional. Although Emhart plants did make use of such equipment as numerical controlled machines (CNCs) computer controlled machines (CNC), programmable controllers, and automated conveyor systems, none of them had attempted to take full advantage of computer technology by developing and/or installing sophisticated computer-integrated manufacturing systems.

By the late 1970's, Emhart's vice president for research and development (R&D) became increasingly concerned about the company's failure to take advantage of existing computer-aided manufacturing technology. He had visited industrial plants in Europe and America where such technology was being applied at advancing levels of sophistication and was active in CAM-I (Computer Aided Manufacturing International) and other technical associations and societies actively engaged in researching and promulgating CAD/CAM² applications. Backed by Emhart's chairman and CEO, the vice president for R&D first attempted to work with division level R&D and operations staffs to instigate projects to test out the feasibility of automating specific processes. He discovered, however, that the daily demands of the production environment consistently took precedence over the projects he had initiated. In the existing atmosphere for technology on Emhart plant floors, there was a preoccupation with products. A key problem was to create awareness of the need to utilize technology for manufacturing processing as well.

Since Emhart, at that time, did not have a central R&D laboratory where company researchers and engineers could work on developing programmable automation applications, the vice president began considering various alternative methods of obtaining an Emhart research center or tapping the capabilities of another center. One possibility was for Emhart to establish a state-of-the-art research laboratory of its own. That was rejected -- not because of the expense, which Emhart could certainly have borne -- but because of two situations:

1. Corporate management's experience made it uncomfortable with the term "research" which had connotations of creating products before there was any strategic analysis of their need, market, etc.

2. New facilities historically consume large amounts of funds and time before they show any results.

Through the corporation's technical staff, Emhart belonged to MIT's Industrial Liaison Program (ILP) as well as the Stanford Research Institute, but little was being made of these resources -- or there was little understanding on how best to use them. The pressures of everyday work, problem solving, and other factors worked against division personnel taking the time to explore best ways to tap those outside resources. On occasion, the corporate technical staff would set up meetings with MIT or Stanford, but there would not be any followthrough. Clearly, a new, more attractive arrangement had to be devised.

Two premises were established. One, if Emhart applied existing technology (not research) properly, it would be competitively ahead. Two, the company had to detach relevant personnel from the daily problems of plant life, perhaps by establishing an applications center at a university where divisional engineers could immerse themselves in study, analysis, and application work. The latter concept caught on and became the catalyst for the MEAC concept with the full blessing of the chairman and CEO. A 3-year experiment was approved.³

According to the manager of Emhart's Robotics Systems Group, the company's objective was not simply "the physical plopping of hardware onto some shop floor." The goal, rather, was to broaden Emhart's technological base by means of true technology transfer -- by transferring not only the hardware and software developed at the research site, but also a full

understanding of the system, to the operating group in which it would eventually be placed. Another Emhart objective was that the applications research plus the design and physical development of the first programmable automation systems were to be completed and the system delivered to Emhart within one year.

Emhart's objectives -- practical engineering applications research culminating in the construction of systems within the space of a year or less -- provided the basis for the criteria used in the selection of a university. Because Emhart conceived of the project in terms of a working partnership whereby Emhart employees and university staff and students would literally work together on the application problems, geographical proximity to the Farmington, Connecticut, headquarters and nearby plants in Connecticut and Massachusetts was a prime consideration. The second criterion -- high scholastic standards and technological expertise -- is an obvious one and needs no further comment. Finally, and perhaps most importantly, the corporation required that the university it selected be able to provide the laboratory and office space it required and be willing to take on short-term application-oriented engineering that adhered to industrial time-lines. The last stipulation was quite significant, since it required, in effect, the university participants to plan work during traditional semester breaks and holidays in order to meet project deadlines.

Before selecting WPI, Emhart representatives considered a number of other universities in the New England area. Some were rejected because they could not offer appropriate facilities and/or could not adapt their schedules to Emhart's time requirements. Others -- the Massachusetts Institute of Technology (MIT), for example -- most certainly met the other criteria but

were organized to do long-term research on a higher level of sophistication than that required by Emhart for its initial venture into hybrid systems applications. In Worcester Polytechnic Institute, Emhart found precisely what it was seeking -- a nearby engineering school with a reputation for scholastic excellence that could, furthermore, supply the facilities and commit to the schedule stipulated. Emhart's choice, however, was conditioned by more than simple logistics and by willingness on the part of WPI. The description in the following section of the organization and prominent characteristics of Worcester Polytechnic Institute is necessary for a full understanding of the appropriateness of Emhart's final selection.

Worcester Polytechnic Institute

WPI is the third oldest science and engineering college in the United States. It was founded in 1865 to train the growing number of engineers who, it was anticipated, would be needed to carry out the work of the Industrial Revolution. The motto it adopted, Lehr und Kunst ("theory and practice" or "knowledge and applied skills") aptly described its educational objectives -- to provide students with both theoretical knowledge and practical experience -- which, at the time, was a unique combination. By the late 1960's, WPI had a long-established reputation as a solid engineering school; it was academically strong and financially sound. An essentially conservative school, it was organized in a hierarchical fashion, whereby the deans and the department heads were responsible for academic affairs (leaving the student body and the faculty relatively powerless). WPI made one inroad into the present by admitting the first female undergraduates in 1968. In December of that year, however, the then-president of the school made a decision that was to revolutionize WPI. That decision was to appoint a panel

of faculty members to conduct a study evaluating the existing strengths and weaknesses of the college and to formulate long-term objectives to serve as the basis of revitalizing the institution.

WPI was, and still is, a predominantly undergraduate school with a relatively small enrollment (1,500 in the late 1960's; approximately 2,400 today) and, because it is a private institution, it has relatively high tuition costs. Its geographical location placed it in competition with both private schools with big reputations, like MIT, and with state schools -- many of which, like the University of Massachusetts, attract excellent students, and all of which had lower tuitions than Worcester Polytech. Another concern, common to schools all over the country at the time, was the demand made by students and faculty alike for "social relevance" in coursework. Aggravating that demand was the fact that the rigid curricula traditional to most engineering colleges made it difficult for WPI students to take advantage of the school's recently expanded humanities electives.

Taking into consideration these and other factors, the faculty panel made a series of recommendations outlining 12 possible approaches for revitalizing the school. Between March and December of 1969, the possible approaches were narrowed down, and the planning was opened to the entire student body and faculty. What emerged was a plan that involved a complete restructuring of the undergraduate program while, at the same time, strengthening the school's original intention, expressed in its motto, to combine theoretical knowledge with practical applications.

The new structure -- now referred to as the WPI Plan or, more familiarly, "the Plan" -- was inaugurated in the Fall of 1970. Because the Plan (which is outlined below) involved sweeping structural changes in the curricula and

educational activities of both students and faculty, WPI representatives recognized that they were "putting the school's reputation on the line." In anticipation of possible objections from the outside world, and to provide themselves with an external evaluation of the Plan's progress, they requested the National Science Foundation (NSF) to appoint a blue ribbon panel to review the progress over a 3-year period. When they turned in their final report in 1975, the panel members -- who began their review in 1972 with grave reservations -- expressed general agreement that the Plan was, indeed, working out in practice.

The WPI Plan

The goal of the Plan is to "develop individuals who are professionally competent in their technical specialty yet are aware of the broader needs of society."⁴ The assumption behind that goal is that "information transfer" -- the traditional educational method employed in lecture courses -- can achieve only limited results. In attempting to develop "competence" rather than to build up a body of information, WPI has institutionalized a variety of methods to supplement the traditional college lecture course. Courses, along with the other methods mentioned below and described in detail in the Appendix, all become tools used by the students as they attempt to develop the ability to learn on their own; solve practical technical problems; evaluate the interaction between technology and society; and explore chosen topics in the humanities in depth.

The primary educational method forming the core of the WPI plan is the project -- actually, a series of projects which require students to use the information they have absorbed through courses and other means to tackle

practical problems and issues. Two of these projects -- the Major Qualifying Project (MQP) and the Interactive Qualifying Project (IQP)⁵ -- are expected to absorb a third of the students' senior and junior years, respectively, and are requirements for graduation. Approximately half of the MQPs and many of the IQPs are sponsored by industries and take place at industrial sites.

Along with the required projects -- which are supplemented by smaller, "prequalifying" projects in the Freshman and Sophomore years -- the two other major elements of the Plan are the "Humanities Sufficiency" and the Competency Examination. These, too, are graduation requirements.

Another revolutionary aspect of the Plan is its approach to coursework. While students are required to take the equivalent of three courses in each of four 7-week semesters per year, they have a great deal of latitude in being able to substitute independent study courses and independent project work for formal coursework. Work done to prepare for and complete qualifying projects also carries equivalent course credit. Another option is known as Individually Prescribed Instruction, which permits students to progress at their own speed through specific areas of study.

Although students do receive grades for coursework or equivalent independent study or project work, WPI does not employ the traditional university grading system. Two grades are possible for coursework: "acceptable" or "acceptable with distinction." If students do not perform acceptably, no record of the performance is entered in their records, and no credit is given for the course. A similar procedure is followed in grading the competency examination: students who receive a grade of "not acceptable" must retake the exam, but no record of the failure is entered on their transcripts.

Another difference between WPI and the majority of engineering colleges is that students are not required to take a specified series of courses and/or course equivalents to obtain a degree in a specific engineering discipline. On the other hand, they are informed from the outset that specified topics must be covered to prepare them for their competency examination, and these topics correspond to the courses recommended by the Accreditation Board for Engineering and Technology (ABET). Students, in other words, are given the responsibility for creating their own course of study and to prepare themselves properly for their qualifying projects, humanities sufficiency, and comprehensive examination. Students are also expected to work closely with their advisors to make certain that they are conducting their educational programs in a reasoned fashion.

According to WPI administrators, the vast majority of the students take the "suggested" series of courses or course equivalents that correspond to ABET requirements.⁶ The associate dean for projects notes that "the system tends to catch nonperformers" and that students do attend formal lecture/lab courses, not to receive credits for graduation, but because they need the information and lab experience to help them perform in their projects, competency examination, and humanities sufficiency. WPI representatives believe that the system creates a "need-to-know" environment that encourages the students to take their coursework seriously. The students interviewed for this study (see pp. 33 to 34) concurred in that belief.

II. MEAC

Establishing "The Plan"

Emhart's vice president of R&D had known about Worcester Polytech in general terms before he embarked on his search to find a university that could accommodate itself to Emhart's applications research objectives. He knew, for example, that WPI had a solid academic reputation and that over half of the incoming Freshmen were in the top 8 percent of their high school classes. Once he actually visited the campus; talked to WPI administrators, faculty, and students; and learned the ins and outs of the WPI plan, he became convinced that "the Plan is a natural for industry." He was particularly impressed with the practical "shirt-sleeves engineering" approach, the project-orientation, and the "competency-based" education that requires the students to demonstrate their professional proficiency through performance in both the projects and the competency examination.

Apart from the fact that both faculty and students were used to working on real world problems in the qualifying projects, the already existing project structure at WPI offered other benefits to Emhart.⁷ Because the projects carry course credits and are required for graduation, the students cannot be paid while working on them. Although Emhart would be responsible for the project costs and administrative fees, then, student labor and faculty advice and assistance were available at no cost. In addition, WPI provided assurances of staff support to help Emhart meet his deadlines by hiring staff engineers (technical appointees with no teaching duties) to aid the students and faculty members who would participate in the Emhart project.⁸ A further

addition has been the use of graduate students, who are paid by the hour with agreement on time and money.

State-of-the-Art Equipment

From WPI's perspective, the project proposed by Emhart would provide the students with MQP opportunities in programmable automation systems. Also -- since it was Emhart's objective to outfit a WPI laboratory with robots and other programmable equipment necessary to conduct the applications engineering and some development -- it would bring state-of-the-art equipment onto the campus and give nonparticipating students and faculty the chance to see, and perhaps use, the equipment. It would also build the expertise of the faculty mentors who would participate in the project and supervise the students, thus building their capacity to supervise future automation projects. The greatest benefit to WPI -- that the MEAC lab established to conduct the Emhart projects would become an ongoing fixture at WPI and would be expanded to include other companies -- was not necessarily foreseen at the beginning and evolved from the success of the collaboration with Emhart.

Initial Planning

The first discussions between Emhart and WPI took place in July 1980. By September of that year, the project outlines had been agreed upon. In the months that followed, legal documents were drawn up and signed, and project participants from both the corporation and the school were identified. Formal management procedures -- regular meetings and written progress reports -- were written into the contract. This required concessions on both sides, since Emhart originally wanted weekly meetings and reports while WPI was used to a

more leisurely pace. Flexibility on both sides resulted in an agreement on monthly reports. Emhart would be responsible for supplying all of the needed equipment, transporting it to WPI, and for bearing project costs (including administration, equipment, maintenance, and some portion of staff salaries) during the development period. Emhart would also supply a project manager responsible for the overall operation of the various applications projects and would assign engineers and, in some instances, factory workers whose jobs were directly related to the project, to work with the WPI participants on the campus. WPI was responsible for providing laboratory and office space for Emhart project staff; a project administrator; students, faculty, and "resident engineers" to work on the project; workshops, demonstrations, and tours for company personnel; and tuition-free coursework for participating company engineers who wished to take advantage of the college's educational programs.

Pilot Projects

The Manufacturing Engineering Applications Center (MEAC) was formally established at WPI in January, 1981. Although the two pilot projects and all of the follow-on projects to date have been developed around the use of industrial robots as the most important subset of the computer-integrated manufacturing systems constructed for the Emhart plants, Emhart corporate representatives had not confined their initial conception of MEAC to robotics applications. In fact, one of the first projects inaugurated was a microelectronics project, which -- because of lack of mutual interest and coupling -- was aborted at a very early stage.⁹ The focus on robotics systems grew out of specific interest in robotics on the part of Emhart division level

personnel and a corresponding interest on the part of WPI faculty and students.

By March 1981, Emhart representatives had chosen the plant sites that would house the new systems and had determined the specific type of robot systems to be developed. Two plants, one from each of two operating groups in the corporation, were selected: a hardware unit which had formed a robotics task force selected a robot application for a loading and materials handling operation; and a fastener plant was selected for a robotics application involving endurance testing of riveting tools. The four corporate members of Emhart's side of the development team moved to their MEAC offices in March, and the actual development work began. No sooner had it begun, however, than a fresh startup problem occurred. The original time-frame for developing the two pilot systems and delivering them to the Emhart divisions was from March through December of 1981. Now, a new directive from the office of Emhart's chairman required that the systems be completed by the end of August. The vice president for R&D, correctly interpreting the new completion date as a calculated challenge to spur motivation, secured WPI's agreement to aim for the new date, and the two pilot projects went ahead faster than had been initially planned.

The new completion date made project management more crucial than ever. Emhart's project manager drew up task-and-target-date statements for each project participant -- student, faculty member, and company engineer alike -- and had everyone involved read and sign the statements to make sure that individual responsibilities were well understood. While the construction of the final systems and the design of many of the parts were completed at MEAC, other parts were designed and built at Emhart divisions, and yet others

were done by vendors. Students working on their MOPs participated as part of the team and were given responsibility for completing the design, construction, and testing of the parts assigned to them and for working on the integration of all the parts during the final stage of construction.

The students worked overtime during the school year and well into the summer to complete their assigned tasks, and both systems were delivered to the Emhart plants on time and fully operational. Emhart's Hardware Division in Berlin, Connecticut, now has an operating computer-aided manufacturing system which has been given the name PLUS (Press Load/Unload System) comprised of a Unimate robot, a part presentation and orientation system, and a sensor system. PLUS automatically loads and unloads doorknobs on and off a forming press and loads them on a trimming press. The system operates two shifts a day and requires no human intervention.¹⁰ The other pilot project resulted in the Rivet Tool Test System (RTTS), now installed in the POP Fasteners Division in Shelton, Connecticut. The Shelton plant produces both rivets and tools used for rivet insertion. Prior to the development of RTTS, the riveting tools had to be manually tested for endurance and accuracy. RTTS is made up of a Unimate PUMA 600 six-axis robot, which automatically tests the rivet tools and can recognize bent or short mandrels, failure of setting, and other faults; a parts feeding and orientation system that feeds rivets to the rivet gun which is actuated by the robot; sensors to generate commands, monitor the robot and respond to dynamic conditions; and a management recording system that can be set to make a typed record of the system's performance at a specified number of cycles or period of time.

Follow-on Projects

The success of the two pilot projects paved the way for other projects. One, completed in January, 1982, gives the PUMA robot utilized in the Rivet Tool Test System the additional capability of investigating automatic POP riveting systems and placing POP rivets in specific hole locations in products requiring riveting.

Emhart's United Shoe Machinery Division in Beverly, Massachusetts, has now installed an ASEA robot that performs an arc welding application -- welding pieces of steel used for the bases of Emhart machines. Participating in the welding project was an Emhart welder, a member of the International Union of Electricians, who joined the Emhart/WPI team of engineers to give them the benefit of his knowledge of both the product and the welding process. Less tangible but every bit as important as the welder's technical knowledge, from Emhart's point of view, was his knowledge of and participation in "the personality of the working place." The welder's "feel" for the task that the robot would perform and how it would fit into the environment of the plant helped the project engineers to develop an applications system precisely suited to the plant's operation.

In addition, the welder (who became the operator and programmer of the welding system once it was installed in the plant) helped to create an atmosphere of enthusiasm for the new system among the other plant workers and eased the transition of the plant's first robotic system into the working environment. The welder spent approximately two days a week for three months at the MEAC lab at WPI. Other plant personnel whose jobs would be affected by the robot system -- the set-up man and the foreman, for example -- were also brought in on the MEAC project by Emhart corporate team members, but to a

lesser degree. (See pp. 25 to 28 for a discussion of Emhart's "full spectrum involvement" approach.)

Two other investigations for feasibility projects were completed. One, a robot system for assembling and welding refrigerator side panels for the company's Hill unit. An interesting part of this project was the use of Emhart's own hot melt (Bostik) adhesive to temporarily hold 15 parts together, without a mechanical jig, prior to the actual welding. This, in turn, led to use of a Unimate robot. The other feasibility study involved a two-robot system utilizing a Seiko and a PUMA together with feeding devices to assemble and test a mechanism consisting of seven discrete components. Since Emhart representatives consider explicit information about this system to be proprietary, no further details are available on it. Stemming from the possibilities revealed in the study, the division has underway a follow-on study for a prototype automated assembly system. It is interesting to note that a TV tape of the activity was a prime "selling tool" for management. Taping is now standard procedure.

Additional MEAC Activities: 1981-2

During MEAC's first two years of operation, 25 students and 5 advisors had the opportunity to engage in projects either directly or indirectly related to the robot-centered systems developed for Emhart. While not all of the student projects resulted in the development of systems installed in Emhart plants, they all fulfilled WPI's major goal of providing its students with real world project experience, and the feasibility studies and other information produced have been of use to Emhart. Emhart has also used MEAC's resources as part of the corporation's Technical Development Program -- an

annual program for engineers from Emhart plants throughout the world that focuses on technological issues for the 1980's and 1990's. The 150 engineers who participate in the week-long program spend a day at MEAC (25 at a time) attending workshops on robotics and a small amount of "hands-on" practice on robotic systems. In addition, WPI representatives estimate that approximately 20 percent of the Emhart personnel who worked on the MEAC projects took advantage of the other educational opportunities open to participating engineers: tuition-free courses which can, if desired, lead to a graduate degree, and free participation in Continuing Education Division seminars and workshops.¹¹

In addition to the students who completed their MOPs under MEAC's auspices, other WPI students benefited from the Emhart-equipped laboratory. Once the first two "hurry-up" projects were completed, the pace in the MEAC laboratory slowed down considerably, thus allowing time for other students to make use of the facilities and the new Emhart-provided equipment that replaced the completed systems. Over 60 students in the senior level computer-aided manufacturing course were able to use the laboratory robots for hands-on programming exercises, and some graduate students are working on theses based on MEAC projects or equipment.

The Center for Technological Innovation: A MEAC Offshoot

As the 2-year experimentation period for the WPI/Emhart partnership drew to a close at the end of 1982, both the school and the company found themselves in substantially altered circumstances relative to those existing when the center was established. The MEAC projects had fulfilled Emhart's goal of not only acquiring the physical systems, but also of transferring the

applications development expertise to divisional employees. With two years of applications experience behind them, the Emhart representatives who participated in MEAC were ready to embark on some development projects that were more sophisticated than those conducted at MEAC and/or were confidential in nature and thus inappropriate for a university environment. Emhart's vice president of R&D, who had initiated the partnership and nursed it along through the experimental period (and later worked closely on the project with his successor, the Vice President for Technology), had by then initiated a second stage applications development plan for the corporation -- an Emhart "Center for Technological Innovation" (CTI) where the higher level applications work now required by the company would be conducted. According to the vice president for R&D, the Center for Technological Innovation -- which is now in operation in Beverly, Massachusetts -- is "a direct offshoot of MEAC" in two senses: first, MEAC's success convinced Emhart's chairman of the benefits of establishing a centralized technology applications center; and second, many of the researchers now at CTI (including three WPI graduates who did their major qualifying projects at MEAC) gained valuable experience through their MEAC project work. Now that they are beyond the initial development and implementation stage in respect to CAD/CAM technology, the Emhart engineers and scientists at CTI are working both with WPI and with universities like MIT on advanced applications. Thus, Emhart is now in the position of being able to form a type of industry/university association that was not appropriate to the firm's needs prior to the MEAC experience.

MEAC Today

While working, on the one hand, to increase their in-house CAD/CAM development capabilities and to forge associations with high level research universities, Emhart representatives continued, on the other hand, to work with and support MEAC. A number of Emhart plants are still in need of the type of feasibility studies and startup development services that MEAC provides, and many aspects of the development work being done at the Center for Technology Innovation are subcontracted, as it were, to MEAC. (One MEAC resident engineer, in fact, spends half of his time at CTI.) While WPI has helped Emhart to progress to a higher level of CAD/CAM development work, Emhart representatives, on their part, have helped WPI to expand MEAC's base. In October, 1982, WPI (with Emhart's assistance) began soliciting other industrial sponsors. By January 1983, Heald Manufacturing Company (a Cincinnati Milacron subsidiary) and the Norton Company had joined Emhart as MEAC sponsors.

In order to perpetuate the type of working relationship achieved through the Emhart partnership, WPI representatives have institutionalized some of the key mechanisms that made MEAC a success during its first two years of operation. The two major mechanisms -- both requirements for MEAC participation -- are 1) a company engineer must take up residence at MEAC at least one day a week for the duration of the project, and 2) a high ranking corporate officer must join the MEAC Industries Advisory board for the duration of the company's membership. Each industrial sponsor pays \$50,000 per year administration fee.¹² They are also responsible for all project

costs and project equipment. In return, WPI provides the same type of services it provided to Emhart in 1981-2: feasibility studies and/or product development in under a year; tours, workshops, and seminars for company employees; laboratory and office space; graduate and undergraduate student support; the opportunity to observe students at work and to recruit them; access to WPI faculty and resident engineers; and tuition-free coursework for company participants.

Current Facilities and Equipment

At this writing, the MEAC facilities were in a state of transition. When MEAC was established, it was located in an old campus building -- one of the original structures built in the 1860's. That building, now being renovated and expanded, will eventually contain a refurbished MEAC laboratory and a WPI CAD/CAM applications center. This will broaden future projects involving additional phases of CAD/CAM linkages. MEAC's temporary location places it close enough to the CAD lab to allow for some experimentation in CAD/CAM hookups.

Because MEAC is organized to utilize company equipment for the duration of the projects, the equipment inventory is constantly changing. MEAC, of course, benefits from this arrangement by being assured of state-of-the-art industrial equipment as long as it has sponsoring companies. As of March, 1983, the equipment inventory included the following robots: a GCA/DKP300V (a donation from the GCA Corporation -- including 2 years of free maintenance), a Unimate-210SF, a Puma 600, an ASEA IRB-60, a Cincinnati Milacron T-3, and a Microbot-TCH teaching robot.

Current Project Activities

Although both Heald and Norton had signed on as MEAC sponsors as this report was being written, the project work for those two firms had not begun. Heald's project will involve a machine loading and unloading operation, with a Cincinnati Milacron robot servicing two machining centers. The Norton project will focus on the development of hybrid systems using robots in conjunction with hard automation to attach metal hubs to grinding wheels.

At present, approximately 28 students are working on major qualifying projects sponsored by Emhart. Four teams of students are working on projects to automate the lock and doorknob polishing and scouring process at one of the Emhart plants. After visiting the Emhart plant and observing the manual polishing operation for locks and doorknobs, the four teams of students and their faculty advisor determined which part of the polishing and scouring operations would best lend themselves to a flexible automation application involving robots. That done, each group of students was free to choose the piece of hardware to develop the application around. Because the process for each part (padlock body, lock shank, or doorknob, for instance) is different, each team is developing a different type of application. One team of two students, for example, is working on a robot system for scouring padlock bodies. Because robots are essentially position control devices and the lock polishing operation requires force control to enable the robot to sense the amount of pressure needed to do the polishing, the students are developing a force controller on the end of the robot's gripper. The force controller will enable the robot to determine where and how to place the lock body in relation to the polishing wheel in a series of positionings and repositionings as the

wheel exerts pressure on the lock body. The precise placement of the padlock held by the robot's gripper, in other words, is determined as a function of how much force is developing against the wheel. In addition, the students are also developing a sensory device to determine when the polishing is complete and, if not complete, to instruct the robot to resume the polishing operation.

Another group of students is working on a "shank taping" process to automate the manual task of placing adhesive tape on the metal shanks put for support in soles and arches of shoes. For this project, the participating students were divided up into competing teams, each of which took a different approach to automating the process. A common problem facing all of the teams was that the shanks — produced to fit various models and sizes of shoes — come in 2,000 different shapes, making it necessary to devise a system to handle and tape variously sized pieces of metal. The two groups working on the problem came up with similar automated systems, both of which are now in the final development and testing stage. One group developed a vacuum-operated feeder which presents the shanks to the robot. The robot is programmed to grip the shank, place it on a tape dispenser (which presents the tape sticky-side-up so that it adheres to the shank); move the taped shank downward to a blade that cuts the tape; and, finally, place the taped shank in a cushioned receiver in a downward motion that smooths the tape around the edges of the shank. Aside from the time constraints placed on the projects (9 months), the students were also required by Emhart to program the robot to complete each shank-taping operation in 10 seconds or less.

Another MEAC major qualifying project -- proposed but not yet begun -- will be the writing of a new operations manual for the GCA robot. Unlike the other two projects, this one is not company sponsored. GCA will, however, be presented with the new manual when it is completed.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY

The projects conducted at MEAC have increased WPI's capacity to provide educational experiences involving programmable automation to its students. In addition, the MEAC project work has enhanced Emhart's capacity to incorporate computer-integrated systems into its manufacturing processes and has led to the establishment of an in-house applications center that further adds to Emhart's ability to apply CAD/CAM technology to plant floor uses. Furthermore, the capacity of MEAC itself has greatly expanded since it was formally established in 1981.

This section evaluates MEAC's present and future potential and discusses its impact as a catalyst to further WPI's focus on CAD/CAM educational activities and Emhart's utilization of CAD/CAM applications. It should be noted at the outset, however, that MEAC, in and of itself, would not be successful had not the necessary preconditions existed at both Emhart and WPI. MEAC's catalytic impact, therefore, must be seen within the context of a number of other factors at both the company and the university.

Emhart Preconditions

The preconditions at Emhart that contributed to MEAC's success include top corporate level direction and support, active guidance and encouragement provided by corporate personnel, and what Emhart representatives describe as

"full spectrum involvement" of managers, supervisors, and workers on the division level. MEAC was initiated by a corporate level vice president who had the support of Emhart's chairman and chief executive and who also made a point of involving, motivating, and supporting the division level personnel who would be participating in the development projects. The corporate support supplied to the participating divisions was substantial: the MEAC program was supported by corporate funds, and corporate representatives made it clear to the division personnel that the risk of failure on the projects was to be shared by the corporate office.¹³ Other, less tangible support was also provided. To overcome resistance on the part of division personnel in the shoe machinery factory where the welding robot was eventually installed, the corporate staff sent the manager, foreman, and welder who would be involved in the future MEAC project to see welding robots in operation at a small factory in North Carolina. According to the foreman, the opportunity to see robots in operation in an environment similar to that in his own plant removed his initial skepticism and encouraged him to support the application project at MEAC. Corporate's "full spectrum involvement" policy was played out in other ways as well. Soon after the decision was made to implement programmable automation projects, corporate representatives began delivering seminars for managers and supervisors in the plants to be involved. At the same time, they held meetings with the officials of the labor union locals, gave them an opportunity to participate in the planned development, and involved the union workers in the actual project work at WPI. The goals of the "full spectrum involvement" approach were 1) to dispel fears by sharing information, 2) to create interest in -- rather than resistance to -- the projects, and 3) to make sure that the new systems would be integrated into both the physical processes and the overall working environment of the plants.

Another aspect of the corporate policy with respect to the automation projects was to give the division engineers operational responsibility for the projects. Although MEAC was supported by corporate (both financially and in terms of responsibility for project failure and/or success), the divisions were responsible for the ongoing in-plant operation of the robot systems and for direct project costs. The management and staff of the various divisions had the ultimate responsibility of choosing (or not choosing) to conduct MEAC projects and of providing staff engineers to oversee the projects.

From Emhart's perspective, the keys to MEAC's success were the project management supplied by the division engineers, the active involvement of the "full spectrum" of employees whose jobs would be affected by the systems, and the existence of a corporate liaison between WPI and the division plants to make sure that the concerns of all sides were addressed while the projects proceeded at full speed. That is not, according to Emhart representatives, to deemphasize the significance of the work done by the WPI students and staff, but to emphasize that in order for the projects to be ultimately successful, the recipients of the systems (the division personnel) would have to have a sense of ownership in them -- both in understanding how the systems operated and in taking some responsibility for their development. In addition, the management supplied by the plant engineers was crucial for keeping the projects to their appointed time-frames.

Some of the preconditions that existed at Emhart -- such as the need to overcome initial resistance on the part of division managers -- may not exist at Norton, Heald, or other companies that may join MEAC in the future. Nevertheless, Emhart representatives believe that not only are support and nurturing on the corporate level necessary ingredients to insure MEAC's

ongoing success, but also direct on-site management. The practical nature of the projects, they believe, requires a shoulder-to-shoulder working relationship which, in turn, requires the type of management provided by Emhart during the experimental period.

Critical, too, to the success of the program was the comprehensive internal communications program initiated with the full support of the corporation's public relations executive. It utilized a wide array of techniques: print, video, graphics, and oratory. For example, the corporation's worldwide newspaper carried 22 news and feature articles on MEAC activity; Emhart's chairman favorably commented on MEAC developments at some 15 internal conferences and seminars before technical staff, management, and financial groups; major magazines were encouraged to report on the program — and several, such as American Machinist and Business Week, did, as did the major area newspapers in Worcester, Boston, and Hartford. The program was cited in the annual reports (1980, 1981, 1982); video clips of MEAC activity were used in corporate presentations to analysts and in video annual report digests to shareholders; and a special video technology update documentary was produced and screened by technical staff in 14 U.S. and 17 overseas plants.

MEAC's Value as a Catalyst for Emhart and Other Firms

If Emhart's experience is to be taken as a model, MEAC's full value as a catalyst for introducing flexible automation systems to member companies is partially dependent on the companies' willingness to participate fully in the projects on corporate, managerial, and technical levels. WPI representatives have taken steps to insure such participation by making top corporate

involvement and project management by company engineers MEAC membership requirements. Of specific educational value to member companies are the opportunities for technology transfer when company engineers and shopfloor workers participate in the development of the computer-integrated manufacturing systems developed at MEAC. MEAC faculty and resident engineers have, by now, over 2 1/2 years of practical experience in solving robotics application problems, and many had previous expertise through prior industrial work. That accumulated experience can be of benefit to company personnel, who, like some of the Emhart engineers, had not previously developed applications systems. The Emhart engineers also found the fresh insights and perspectives brought to bear by the students often aided the development process. Thus, although the students who will participate in MEAC in the future may not have actual prior experience in computer-aided manufacturing applications, their approaches to solving the problems at hand can aid in the technology transfer process.

The seminars, workshops, demonstrations, and coursework available to participating engineers offer related educational opportunities. WPI's Continuing Education Division offers 2-day introductory seminars on programmable controllers and on CAD/CAM concepts, systems, and applications. Also offered by the Continuing Education school is a one-day "executive briefing" on factory automation covering the state-of-the-art of the technology, action plans for implementing manufacturing automation, possible problems and their solutions, and future directions of CAD/CAM. All of the above seminars are taught by working professionals. In addition, Continuing Education offers graduate courses in Mechanical Engineering, Electrical and Computer Engineering and other disciplines which can be taken as advanced

study courses or as part of degree programs leading to Master of Science or Master of Business Administration degrees.

Participating MEAC company engineers may also take advantage of regular undergraduate and graduate courses. WPI's computer-aided design (CAD) laboratory, which opened in 1981, offers a variety of introductory courses. Semester-long lecture/lab courses, individually prescribed instruction (see Appendix), self-paced audio/print courses, week-long minicourses, and shorter seminars are all available to company participants. In addition, the CAD lab — equipped with three Computervision terminals using CADDS 3 software — is available 24 hours a day to those students who have been tested out on the equipment. Also available is an Apple microcomputer laboratory used, in part, for a basic computer graphics course focusing on how to program the computers to do graphics functions. Courses in the writing of programs for turnkey graphics systems are also offered. A course in computer-aided manufacturing provides instruction in techniques used for monitoring, controlling, and optimizing manufacturing and laboratory practice on the MEAC robots and the CNC (computer numerical control) machines in the school's manufacturing laboratory. Other courses covering such topics as computer methods in mechanics, machine design applications, creative design (computer-aided and other techniques used in the creation, analysis, and evaluation of mechanical designs), data base design, real time programming, and software engineering are also offered as part of the regular undergraduate curricula available to company engineers.

It is also possible for company engineers to enter a WPI graduate program (in Mechanical Engineering or other disciplines). This, too, is available on a tuition-free basis. Work toward a graduate degree can take two forms. The

company engineer can either take graduate courses while continuing to work full-time for the company, or, if both the individual and the company wish, take a leave of absence to pursue full-time graduate work. In both cases, the work done by the engineer on the company MEAC project could become the basis for his or her master's thesis.

Union workers and other company participants may take advantage of seminars, workshops, and demonstrations provided by MEAC.

MEAC'S Value as a Catalyst at WPI

Prior to MEAC's establishment in January 1981, WPI offered few formal courses in computer-aided manufacturing and design. Although the Apple lab and a manufacturing lab (containing CNC machines, microprocessors, and conventional manufacturing equipment) did provide facilities and equipment for some basic CAD and CAM applications work and hands-on practice, the school did not have state-of-the-art equipment for use in teaching, on-campus project work, and graduate and faculty research. The currently offered computer-aided manufacturing course did exist before MEAC was established, but it was much more lecture oriented than it is now because of lack of equipment for laboratory work. Further, there were only a handful of Major Qualifying Projects in the CAD/CAM area before the creation of the Manufacturing Engineering Applications Center — partly because of lack of opportunities in local firms and partly because too few faculty members had enough practical expertise to serve as project monitors. Some of the growth in computer-aided equipment, CAD and CAM course offerings, and research over the past 2 1/2 years occurred independently of MEAC. The Computervision equipment contained in the CAD lab, for example, was the result of a sizeable donation from the

class of 1956 together with equipment grants from Computervision itself, and some WPI faculty members had conducted individual CAD/CAM research prior to MEAC's establishment. Although it is not possible, in all instances, to make clear distinctions between growth directly attributable to MEAC and that resulting from the school's general focus on including modern industrial practices and techniques in the education provided to its students, certain results can be directly attributed to MEAC. The state-of-the-art equipment in the MEAC laboratory has opened up a wide range of hands-on activities apart from the MQPs associated with company projects. As mentioned previously, students in the computer-aided manufacturing course use the robots to gain programming experience, and graduate students use them for thesis work. The GCA robot is being used for faculty-sponsored MQPs, and individual faculty members use the equipment for research on vision systems and artificial intelligence.

According to MEAC's director and chairman of the Mechanical Engineering Department, more and more of the "better students" who once gravitated toward research and development, are now going into manufacturing. While this trend is partially a result of the increased attention given to manufacturing in the media and in professional circles, the existence of the Manufacturing Engineering Applications Center on the WPI campus gives interested students the opportunity to see applications research in action and to participate via project work.

Increased Student Interest

When MEAC was established, 10 students chose to do their MOPs on the manufacturing applications research and development projects at the center. That number grew to 25 in the 1982-3 academic year, and there are now 50 additional students interested in working on MEAC projects for the 1983-4 academic year. Ten students who were in the process of completing their major qualifying projects at MEAC in the Spring of 1983 were interviewed for the present study. All of those interviewed expressed general agreement with the student who said that he chose a MEAC project because a graduating engineer "wouldn't be worth much if he just stuck to a strict mechanical engineering discipline without learning the various uses of computers in manufacturing or other forms of engineering."

All of the students said that their project experience was extremely valuable -- not only as an educational experience in itself but in building a type of self-confidence they believed would aid them in job interviews and in their professional careers. According to one student, the project gave him a chance to take what he learned in the courses and apply it to an actual industrial problem while the knowledge was "still fresh" in his head. Another added that the work done on the project "not only teaches what you would have learned in a course, but also provides practical experience and helps you make the connection between different courses and see how they're all interrelated." Another felt that the experience of dealing with the complications that arise in practical applications problems was of most value, while yet another pointed out the value of having to give frequent oral presentations to faculty and, especially, to company engineers and executives. From the students' point of view, the projects were an integral

part of the overall education at WPI. Said one: "I think the programs at this school are set up so that at the end of your stay here, you're able to attack a problem that you've never seen before and apply fundamental theories that you've learned in book-learning courses to that problem. You wind up knowing how to apply what you know because of your project work and your competency exam." All of the students spoke of the projects and the competency examinations as experiences in which "it all came together."

At the time of the research for this study, most of the students (all of whom were seniors) had been through at least one employment interview. Those students commented on the self-confidence they felt they had gained through their project experiences -- a self-confidence which they believe was helpful to them during their job interviews. Aside from having proved to themselves and to the faculty that they could find workable solutions to real-world engineering problems, they were also able to tell the interviewers that they had solved a specific automation problem for Emhart and could discuss their approaches, methods, techniques, and specific solutions.

Placement

All but two of the students who completed MQPs at MEAC during its first year and a half of operation have found jobs as engineers. Emhart created "technical associate" positions and hired, at corporate expense, the first three MEAC graduates. They were then rotated around Emhart divisions for 18 months. On completion, they had each received job offers from various divisions. Since the WPI placement office does not keep records of the specifics of the positions accepted, it is unknown whether any but the Emhart jobs involve computer-aided manufacturing. One of the students who is not now

working is a WPI graduate student doing thesis work at MEAC, and the other is "still looking." All of the 28 students who completed their MOPs at MEAC and who graduated in June 1983 have either been offered jobs or are attending graduate school.

Bringing the Factory onto the Campus

A significant way in which MEAC directly benefits WPI is that it, in effect, brings the factory to the campus. Not only does it bring in state-of-the-art industrial equipment, but it also brings in professional engineers to work with the faculty and students. The recent expansion of MEAC to include other industries apart from Emhart should increase the value of the engineer-on-campus concept by giving students the opportunity to come in contact with professionals from different companies with different needs, perspectives, and operating procedures.

Although immediate MEAC plans focus on individual projects for individual companies, MEAC representatives believe that it may be possible for the participating firms to cooperate in some jointly sponsored projects aimed at common application problems. This situation, if it does arise, will enable the students to interact in a work situation with a variety of professional engineers.

Although Emhart's original goal was, in part, to provide a production-free environment for those of its engineers who would be working on applications research, some elements of the working place had, of necessity, to be brought on to the campus. Obviously, equipment had to be transferred to MEAC. In the case of the Rivet Tool Test System, all of the actual components of the system were brought on to the campus. In the case of the Press

Unload/Load System, the presses themselves were too large to transport and store at MEAC, so some of the equipment had to be simulated. In both cases (and in the follow-on projects), the actual hardware environment of the specific operation in the factory was recreated or simulated. In addition, the time requirements, the requirements placed on materials and equipment to be used, and the project management supplied by the company engineer also simulated the workplace environment by placing the students in a situation in which real-world constraints and necessities held sway.

While a large number of WPI students who participate in the cooperative education program and/or complete industry-sponsored MQPs in a factory environment receive a similar kind of educational experience in industrial practices and procedures, MEAC -- by bringing the factory onto the campus -- expands the potential for a larger number of students and faculty to interact with professional engineers on a regular basis. At the same time, the equipment is on campus and available for educational purposes to a large segment of the academic community.

Future Potential of MEAC

The growth of student and company interest in MEAC is a strong indication of the center's future potential. While lab space may become a temporary problem when the Norton and Heald projects get underway, the new facilities now being constructed to house the center and other labs should provide the additional needed space by September 1983. The mechanism established to govern industrial membership guarantees a constant influx of state-of-the-art equipment as long as companies remain interested and responsive. Furthermore, WPI representatives hope to encourage the member firms to donate robots and

other equipment to provide the center with a stable inventory of equipment for use in teaching and research. WPI has already been the recipient of two outright gifts: the GCA robot and a Puma donated by Emhart. WPI representatives believe that the center's distinctive goal -- that of directly transferring state-of-the-art applications research into industrial practice -- may encourage further industrial donations and participation.

Other major industries have also expressed interest in joining MEAC, but the MEAC directors are, at this stage, limiting MEAC membership to 4 or 5 companies for a number of reasons. In the first place, space will be limited until the new facilities are completed. Secondly, they want to make sure that the project needs of the member companies are met without placing undue strain on both students and faculty participants. Third, since MEAC is primarily an educational center, from WPI's perspective, they want to make sure that the needs of the participating firms do not overwhelm the educational activities of the laboratory.

Potential Problems

Scheduling is a problem, even now when only Emhart projects are being conducted. Careful planning is required to make use of free time of the students in the computer-aided manufacturing course to get programming practice while not disrupting application research activities. With three participating MEAC companies, increased numbers of students working on MOPs, and more and more students signing up for the computer-aided manufacturing course, scheduling could become even more problematic. Another future problem area is financial planning. Financial record-keeping problems did occur in

the first two Emhart years and — as in the case of scheduling — could increase with the addition of more firms and more participating students.

MEAC directors and staff members are aware of these potential problems and are taking steps to prevent their occurrence. Because complications that may arise in the industrial projects cannot be predicted, equipment usage for class purposes cannot be tightly scheduled, so the planning must allow for flexibility. The directors of MEAC will soon hire a laboratory manager to handle bookkeeping and scheduling.

Emhart's ex-vice-president for R&D (who stepped down but assumed the new title of senior fellow, technology) developed such an intense involvement with MEAC that he is now listed as an adjunct faculty member at WPI and spends a significant portion of his time publicizing MEAC to other firms and developing mechanisms to insure MEAC's ongoing success.¹⁴ Because of the nature of MEAC's projects — requiring top corporate support and day-to-day interaction with engineers on the plant or divisional level — Emhart's Senior Fellow for Technology believes that companies should provide "arbitrators" who can work with both plant personnel and WPI participants to anticipate and head off problems and make sure that both the companies and the school are constantly aware of each other's needs and capabilities. He also warns that the dynamic situation of working on new problems with new industrial participants and an annually changing group of students requires continued attention, constant reviews, and the flexibility to adapt to new situations. WPI representatives are, again, aware of these needs and have expressed their intention to keep close tabs on MEAC's progress.

Future Plans

Apart from the expansion in industry membership, MEAC representatives are also looking at ways to expand the nature of the applications work done at the center. MEAC's success with robotics applications projects is now considered to be a model for potential activities in other areas of computer-aided manufacturing. What those specific areas will be will depend on the requirements of the participating companies, faculty and WPI resident engineer expertise, and student interest. One area of immediate interest would involve projects using the Computervision terminals in the CAD lab to program the MEAC robots. Another area of interest would involve the School of Management in Interactive Qualifying Projects¹⁵ on project management and/or in delivering management courses to participating company employees. A number of related IQPs could evaluate the responses of workers, union officials, and management personnel involved in the automation projects conducted at MEAC and their responses to the problems and benefits of the systems once they are installed on the plant floor.

WPI's Future Capacity to Meet CAD/CAM Education Needs

WPI representatives believe that the school's project-oriented approach provides a built-in mechanism that allows both faculty and students to go through "a natural professional development that keeps them at the state-of-the-art in their practitioner and educational studies in a way that few programs of study can do." Certainly the projects, over half of which are proposed by industry, require that the faculty advisors be capable of responding to industrial needs and problems. The WPI faculty, therefore, may have an even greater impetus to keep up with industrial practices and

developments than those in more traditionally structured engineering schools. The projects have been described as the "life-blood" of the WPI Plan. If faculty cannot or do not respond to industry-sponsored projects, that lifeblood will be siphoned away.

The MEAC projects and other CAD or CAM projects conducted through the CAD lab and with companies like DEC, the Foxboro Company, Sea-Con Services, Inc., Hewlett Packard, and the Jamesbury Corporation, indicate that the faculty has been able to respond and will continue to do so. Like the faculties of other universities included in this case study series, the WPI faculty is not universally "computer literate" (although estimates of faculty computer literacy range from 75 to 90 percent), nor are all the faculty in mechanical engineering and related engineering disciplines involved in or knowledgeable about CAD/CAM. While it is not, perhaps, necessary or even wise for all faculty members to be involved in teaching or monitoring projects on programmable automation, WPI has provided a number of channels for interested faculty to increase their knowledge. Computer-aided design seminars have been held for faculty members, and some have attended Computervision customer courses. Faculty as well as students can take the Individually Prescribed Instruction (IPI) CAD course and can attend the Continuing Education courses on programmable controllers and CAD/CAM. In addition, the Technical Development Programs in robotics and computer integrated manufacturing held for MEAC company employees (see pp. 18 to 19) are also open to WPI faculty.

At present, WPI is experiencing some difficulty in accommodating the numbers of students interested in aspects of CAD and CAM. The CAD lab has a waiting list of 80 students interested in taking the computer-aided design course; MEAC will accommodate the 50 students who have signed up for MOPs, but

this will entail hiring new faculty members. The projects office has more requests from students wanting to do their MQPs in industries offering CAD/CAM projects than it has industries offering such opportunities. The Cooperative Education office has experienced a similar lack of industrial opportunities, but hopes to be able to tie in to the MEAC companies to open up co-op programs with them.

Considering the advances made by WPI in the past three years, however, and considering the value of the industrial projects as a means of keeping pace with the practices of local industry, WPI seems to be well poised to expand its CAD/CAM educational programs in a timely fashion. CAD/CAM is perhaps a misnomer in this context. Computer-aided engineering (CAE), encompassing CAD and CAM and other computer-aided engineering technologies may be more appropriate. Future plans to address CAE are to introduce CAD at the freshman level and to link the CAD training with numerical control programming on CAD terminals to the actual part production on the CNCs in the CAM lab (this is being done now, although not at the freshman level). The next step would involve the creation of CAD/CAM projects -- and this, in turn, would require integrating and cross-training faculty who have previously been involved primarily in either graphics or manufacturing processing. The junior level CAM course, which currently serves approximately 60 students, will be offered more frequently or be split into sections. Additional courses may be added in the area of vision systems for robots and other areas of flexible automation.

On the graduate level a new M.S. program in manufacturing engineering is now being developed and will be offered in September of this year. Students in this program will work through individualized courses of study based on

their prior background and perceived needs and deficiencies. The master's degree in manufacturing engineering can, therefore, be focussed on computer-aided manufacturing if the student desires. Five new graduate courses focusing on various aspects of computer-aided manufacturing will be developed for students pursuing the manufacturing degree.

WPI has the flexibility to move rapidly to meet the need for computer-aided engineering education primarily because of the internal mechanisms of the WPI Plan. David Reisman, the Henry Ford II professor of social science at Harvard University and a member of the NSF panel that evaluated the WPI plan during its first years of operation, said of WPI: "Some of the best chances for reform are in institutions with a loyalist faculty...who care about the institution's survival in part out of loyalty and idealism, and in part because it is the only source of their own academic survival. The best chance for reform of undergraduate curricula may lie precisely in the more conservative institutions."

The creators of the WPI Plan turned a conservative institution into a model of innovation which has had continued success for over 12 years. Emhart, attempting to introduce robotics applications to its plants by beginning with a few test cases in a few plants, also acted in an enlightened, yet conservative, fashion. Together, these two "conservative" organizations have created in MEAC a unique and truly innovative means of walking the fine line between serving industry's needs and serving the educational needs of the students without making education the servant of industry.

FOOTNOTES

1. Fortune, May 2, 1983, p. 226 ff.
 2. Computer-aided manufacturing and computer-aided design.
 3. Late in 1982, Emhart did establish a "Center for Technological Innovation." The center, according to the vice president of R&D -- now retired from that position but still a full-time employee as senior fellow for technology -- is a direct offshoot of MEAC and is now one of MEAC's "customers" (see p. 19).
 4. Worcester Polytechnic Institute (Informational Brochure), p. 7.
 5. See Appendix for details.
 6. During its last accreditation visit to WPI, the ABET panel expressed some concern that the structure of the Plan made it impossible for WPI administrators to provide guarantees that all graduating seniors in the accredited engineering disciplines had completed courses or course equivalents in all of the topic areas required for accreditation. ABET subject area guidelines include the following key topic areas:
 - 1/2 year of basic sciences
 - 1/2 year of mathematics
 - 1/2 year of engineering design
 - 1 year of engineering science
- The ABET panel recommended that the WPI plan be slightly modified to include assurances that all engineering students receive "full coverage" of the ABET-required topic areas and that the WPI staff provide evaluations demonstrating that each student has done so. ABET's executive director states that the Accreditation Board will leave the precise method for insuring topic coverage to WPI administrators and faculty. ABET's primary concern, in other words, is that assurances be given, not the method of providing those assurances or the educational methods employed by WPI.
- WPI administrators are reasonably certain that they can provide those assurances without substantially altering the Plan. One suggestion, proposed by the Mechanical Engineering Department, would be to set up an internal accreditation group within each department to conduct individual evaluations for students to demonstrate "competence" in each ABET-required topic area. The student could demonstrate competence by 1) taking formal courses in the subject area (either lecture courses, individually prescribed instruction, or independent study), 2) completing projects in the area, or 3) passing a subject area examination.
7. See Appendix, pp. 1 to 111.
 8. See pp. 25 to 28 for other benefits to Emhart.

9. However, the microelectronics work was continued in space offered by the Machinery Division in Beverly, MA, and subsequently became the core for the Center for Technological Innovation there.

10. No Emhart employees have been displaced by the new robot systems to date. The worker who was previously responsible for loading and unloading the presses has been transferred to another area. The rivet tool testing job was a repetitive and boring one for which few volunteers could be found. Those that did take on the job, according to Emhart representatives, could not be retained for any length of time. Furthermore, people did not maintain as reliable records as the automated systems.

11. See pp. 29 to 31 for educational opportunities for Emhart management personnel and participating workers.

12. The administration fee helps cover the cost of a full-time technical director, a technical specialist for maintenance of the robotic systems and equipment, lab supplies, a secretary, office, and supplies.

13. While the actual projects at MEAC were paid for by the divisions, corporate funds paid for overhead associated with the MEAC program.

14. His successor's title, vice president, technology, traces, in part, the practical success of the MEAC program and the corresponding buildup within Emhart for concentrated effort to harness state-of-the-art technology. The internal spinoffs are varied: the CTI itself, the many programs on microelectronics, CAD/CAM systems, and the creation of a special technology committee of the Board of Directors with whom the vice president of technology meets periodically for briefings.

15. See Appendix.

MANUFACTURING ENGINEERING APPLICATIONS CENTER (MEAC)

Worcester, MA

APPENDIX

THE WPI PLAN

The Major Qualifying Project (MQP) focuses on the application of specific quantitative and technical methods in the students' major field.¹ The MQP can take a variety of forms, from designing and/or constructing a new device or process, to exploring solutions to industrial problems. Approximately 50 percent of the projects are proposed by local industries, and the balance are proposed by the faculty.² Students may work singly or in teams, although the team approach is the one recommended by the faculty. A large number of students do their project work off-campus at a local industry, where they participate in currently operating industrial projects. Students who do not actually work in an industrial environment are still required to meet the same type of deadlines and complete the same type of planning and project design they would do in industry. In addition, students who work on-campus must arrange for laboratory and equipment time and must plan and budget their use of materials. WPI's Computer-aided design lab, opened in 1981, has generated a number of MQPs sponsored by local firms, most of which proposed projects that would help them solve existing engineering design problems. One student, for example, completed a project testing out the use of computer aided design systems in the manufacture of forging for the Wyman-Gordon Company.³ MEAC

itself has generated a number of major qualifying projects in which 25 students have participated with Emhart engineers to design and build applications systems for Emhart division plants. (These projects are described in Section II.) Students must submit regular reports and are reviewed periodically by their project advisors. At the completion of the project, students prepare a written report summarizing their findings and frequently deliver oral reports to executives of the sponsoring company and/or to faculty and students on the campus.⁴

Interactive Qualifying Projects (IQPs) involve the interaction between society and technology and focus on how technological solutions and problems affect human needs and values.⁵ The object, according to the WPI Catalogue, is "to make the student sensitive to general social problems; able to question, criticize or reinforce prevailing ethics and value concepts; aware of societal-humanistic-technological interactions; able to analyze these interactions and make better judgments and policy recommendations on issues that affect society." One recent IQP explored "Computer Privacy and Implications of Computer Society;" another examined the accident at Three Mile Island, focusing on the possible risks to public health imposed by the radiation releases and technical malfunctions. Students working on IQPs often work with public and private agencies as well as with industrial sponsors. A satellite campus in Washington, D. C., called the Washington Project Center, provides the opportunity for 25 students per term to live in Washington while completing projects sponsored by Congressional offices and such agencies and organizations as the Small Business Administration, the National Association of Manufacturers, the National Research Council, the Patent and Trademark Office, and the Department of Commerce. One project, sponsored by a Senator's office, dealt with "Engineering Manpower as a National Priority." The project

resulted in a 373-page document describing the causes of the engineer shortage in the United States, together with a cross analysis of American, Japanese, and West German educational process; an analysis of U. S. legislation aimed at improving the technological manpower base in the country; and recommendations for action.

Aside from the Washington Project Center, WPI maintains three other off-campus project centers: one at Digital Equipment Company, where students engage in major qualifying projects in such areas as CAD/CAM integration, interactive data analysis, small systems reliability, and interactive CAD placement; another at the Norton Company, a diversified multinational manufacturing firm, where students complete both major and interactive qualifying projects; and the third at St. Vincent's Hospital/University of Massachusetts Medical Center, which provides students with the opportunity to study and attempt to solve biomedical problems through the application of engineering and scientific principles.

The Humanities Sufficiency usually consists of five thematically-related courses in a chosen area of the humanities, culminating in a sixth course -- an independent study in which the student draws upon the five previous courses to produce a research paper or a critical essay on the chosen theme.⁶ Students are responsible for consulting with members of the humanities faculty to determine the general subject area and the specific theme, and for constructing a series of courses that will prepare them to complete the final essay. Although the essay is the most typical means of completing the Humanities Sufficiency, students may also choose to give a performance, write a series of poems, short stories, or a novelette, or -- if they are unusually well prepared in the humanities -- take an individually

prepared examination in place of the six courses. WPI's dean of the faculty describes the Humanities Sufficiency as the "post hole approach" -- by encouraging students to dig deeply into one area of the humanities, the faculty hopes to raise a genuine interest in at least one aspect of the area which may, in turn, be broadened later on the student's own initiative. The Humanities Sufficiency is also designed to teach students to make use of modes of thought and judgment different from those employed in engineering and the sciences and to develop an appreciation for the methods so employed.⁷

The Competency Examination, normally taken after the end of the Junior year, is designed to have the student demonstrate that he or she has competence in the major field of study and is able to perform on the level of a beginning professional. The examinations, which differ slightly from department to department, require students to "attack the kind of problem that may reasonably be encountered in a professional situation." While the Major Qualifying Project focuses on a chosen area of interest within the student's field, the examination requires students to demonstrate a solid command of the broad body of knowledge comprising his or her discipline. This is elicited by presenting the students with a problem that is broad enough to call on a wide range of knowledge within the field, yet focused enough so that students are called upon to identify and employ knowledge of specific methods, processes, principles, and theories. For example, Mechanical Engineering examinees may be asked to design a means to transport a specified number of pounds of molten aluminum from the furnace to the mold station of a plant. The examinees' designs are required to meet precise task specifications and to be presented in the form of a professional report containing design drawings, calculations, material specifications, and other data.

Students normally have 48 hours in which to complete the take-home problem. This is followed by an oral examination by the three faculty members on the student's examination board. The written and the oral, taken together, should demonstrate the student's capacity to attack a new problem in an appropriate manner, complete it in a designated time-frame, and perform adequately under the pressure of an oral examination.

In Individually Prescribed Instruction (IPI), "Students work primarily by themselves from written study guides for each unit of work. The study guides state specific objectives and suggest ways of accomplishing them. These ways may include readings in conventional textbooks, working problems, doing experiments, and/or viewing videotapes or other audiovisual aids. Students can get help from their instructor or from tutors at scheduled periods. When students feel they have mastered the objectives of a study unit, they come to a scheduled class to take a written test or assessment. This test is graded immediately, with the student present, on a pass or no-pass basis. If students pass, they go on to the next unit. If they do not, they must try another test on the same unit after more study. What counts is ultimately passing the unit. Grades are based on the successful completion of a specified number of units. Class periods are not used for lecture-recitation but to give the tests and to consult with students on individual problems." (WPI Undergraduate Catalogue)

FOOTNOTES

1. WPI has four major degree programs accredited by ABET: Civil, Chemical, Mechanical, and Electrical Engineering. Although the majority of students complete programs in those four fields, "students may 'major' in any area in which the WPI faculty is competent both to help them learn and to test their performance on a suitable professional level" (WPI Catalogue, p. 42). Students have taken degrees in such fields as Biomedical Engineering, Environmental Planning, Humanities/Technology, Management, Nuclear Science, English, History, and Physics (to name but a few). Since almost 75 percent of the students complete degrees in the four accredited engineering disciplines mentioned above, and since the object of this section of the present report is to describe the engineering education at WPI, the descriptions of the Plan elements that follow will all focus on the undergraduate engineer as the typical student.

2. Students can also initiate projects by proposing project ideas to faculty members who may then formally propose the projects.

3. WPI Journal.

4. WPI's associate dean for projects describes the project program as one which is similar to cooperative education programs, the major differences being 1) the students working on projects are under faculty supervision and are graded by the faculty, and 2) the students cannot be paid for their work by industrial sponsors.

WPI also operates an active cooperative education program. This program is similar to co-op programs in other schools (see case study #7, Brigham Young University, and case study #3, University of Michigan) except that the work period in industry is longer than usual (8 months at a time, as compared to 3 or 4 months at a stretch in programs sponsored by most schools). The program places approximately 120 students a year in co-op positions at 50 to 60 companies.

5. WPI Brochure, p. 8.

6. The term "sufficiency" indicates a thematically-related course and project sequence "sufficient" to allow students to acquire an idea of how knowledge is obtained and expressed in a nontechnical discipline (WPI Catalogue, p. 35). The Humanities Sufficiency is usually completed in the sophomore or junior year.

7. WPI's membership in the "Worcester Consortium" provides another avenue for the study of the humanities. The Worcester Consortium is a 13-year-old program whereby students registered at WPI and 9 other post-secondary institutions in the city may take courses at any of the other schools free of tuition charges when those courses are not offered at their home schools. Most of the WPI students who take advantage of this program (approximately 50 to 75 students per year) do so in order to take language or liberal arts courses not offered at WPI. Students from the other consortium institutions who take courses at WPI (again, approximately 50 to 75 each year) normally take computer science courses or courses in the other sciences rather than engineering.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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Part C - Individual Education and Training Case Studies

- C.1--CINCINNATI MILACRON INDUSTRIES, INC.
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- C.3--BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS
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Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.6— New England Programmable Automation
Customer Training: Computervision, GCA,
Automatix**

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

NEW ENGLAND PROGRAMMABLE AUTOMATION CUSTOMER TRAINING:
COMPUTERVISION, GCA, AUTOMATIX

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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

NEW ENGLAND PROGRAMMABLE AUTOMATION CUSTOMER TRAINING

Computervision, GCA, Automatix

INTRODUCTION

This study departs from the others in the "manufacturing automation" education and training case study series in that it profiles the customer training provided by three programmable equipment vendors, rather than, as is done in the other studies, exploring one company, school, or training program in depth. The three training organizations profiled are Computervision, a major producer of computer-aided design (CAD) equipment; GCA, a producer of programmable semiconductor manufacturing equipment and other products and services; and Automatix, a recently established robotic and vision systems firm. The corporate headquarters of all the firms are located near route 128, the Boston area circumferential highway that has attracted a number of high technology firms. None of the firms described here, however, confines its business to the Boston area; they all maintain national and international plants or offices and conduct the majority of their business outside of New England.

Although all three companies deliver formal customer training courses based on the skills and information required to operate and/or maintain programmable equipment, there are more differences than similarities in the type of training required to support each system.

A major difference in the training is related to the different uses for which the systems were designed. Computervision CAD systems -- which replace the drafting board and design table -- are built for a high degree of operator

interaction. Automatix' and GCA's computer-aided manufacturing equipment is designed to reduce operator interaction to the bare minimum. Training on those two systems focuses as much or more on maintenance as on system operation.

While the primary object of this study is to describe the variety of training approaches observed in the three companies, a secondary objective is to point out some similarities that transcend the quite significant differences deriving from the nature of the equipment, the size of the vendor company, the years of customer training experience, and the market for the equipment. The similarities, however, are best understood after a clear sense of the differences is established. Sections I to III of this report contain individual profiles of the three training organizations. Section IV discusses common and unique problems, present training capacity, and future plans.

I. COMPUTERVISION CORPORATION

Computervision is the largest turnkey, or stand-alone, CAD/CAM equipment vendor in the United States.¹ In contrast to a number of other major CAD/CAM equipment vendors, Computervision concentrates entirely on producing, selling,

1. CAD/CAM equipment, in this instance, refers to computer-aided design and drafting systems having the capability to produce computer numerical control data that can be fed, through a postprocessor, to CNC machines, robots (potentially) and other computer-aided manufacturing equipment. Computervision has had the largest market share of the turnkey CAD/CAM market since the late 1970's (31 percent in 1979 and 1981, 33 percent in 1980; Merrill Lynch estimates 29 percent for 1982 and 27 percent in 1983.) In spite of competition from IBM's mainframe-based CAD/CAM systems and from Intergraph (a new entrant into the top three CAD/CAM vendor list), Merrill Lynch anticipates that "by 1984 a more technically competitive CVN (Computervision) may well regain some of that lost share." Computervision's new 32-bit minicomputer is due to come onto the market in September 1983. (See case study #6 — CADAM Inc — for a discussion of mainframe vs. minicomputer based CAD/CAM systems.)

and supporting CAD/CAM hardware and software. IBM, Computervision's closest competitor in the CAD/CAM market, sells its own hardware and licenses third-party software. Other major competitors, Applicon and Calma, are now subsidiaries of large corporations — Schlumberger, Ltd., and GE, respectively — which are also active in industrial markets other than CAD/CAM equipment and services.

Computervision was founded in 1969 as a producer of photoplotters.² Its first CAD/CAM system, using CADDs 1 (computer-aided design and drafting) software, was produced in 1971. CADDs 2 software, a specialized product for integrated circuit design, came out in the midseventies. CADDs 3 — a multi-applications software package with options for mechanical design, electrical schematics/printed circuit board design, wiring diagrams, architectural and facilities design, tool path designs for numerical control machines, and industrial piping and instrumentation diagrams — came on the market in 1975-76. CADDs 4, an enhancement of CADDs 3, was first marketed in 1980; and CADDs 4X — which has a solids modeling option and was developed for use with Computervision's new 32-bit minicomputer and enhanced graphics processor — will appear on the market in the summer of 1983.

The corporation now employs approximately 4,400 people in various locations in the United States, Europe, Asia, and Australia. Corporate headquarters are located in Bedford, Mass.; 13 district offices are spread throughout the United States; and 16 international offices are located in England, France, Italy, the Netherlands, Japan, and other countries. North

2. Photoplotters are used to produce integrated circuit artwork through high-precision exposure of photosensitive materials. (Turnkey CAD/CAM Computer Graphics, A Survey and Buyer's Guide for Manufacturers, 4-2)

American sales account for approximately half of the total Computervision market, with European sales accounting for 40 percent, and the remainder in Asia. Approximately 1,400 Computervision systems (containing 1 to 6 graphics terminals apiece) have been installed to date in the North American Service area in an estimated 500 locations. The average system -- including a central processing unit, graphics terminals, peripheral hardware, and approximately 10 software options -- sells for \$500,000.

COMPUTERVISION EDUCATIONAL SERVICES: CUSTOMER TRAINING OVERVIEW

Computervision's training department, referred to as educational services, offers a wide range of basic and advanced courses for users and programmers of CADDs 2, 3, and 4 software.³ A total of 33 discrete courses are currently offered; 5 new CADDs 4 courses are under development; and plans are now being made to develop new 4X courses, along with "conversion courses" for customers trained on CADDs 3 or 4 who will convert their systems to 4X. (A CADDs 3 to CADDs 4 conversion course already exists.) A general overview of the courses is provided on pages 13 to 15 following a description of the organization, philosophy, staff, and facilities of the educational services department.

Educational Services Department: Past Development and Current Organization

Computervision began offering regularly scheduled customer training courses in 1974. By 1979, there were three full-time trainers and a training manager, who coordinated the delivery of the five regularly offered courses

3. Although there are still some CADDs 1 systems in use in customer plants, CADDs 1 training is no longer available.

then available. By the end of April 1983, Computervision had 33 instructors — 20 in its national training center in Woburn, Mass., and the remainder located in the 3 regional training centers.

Relationships with Other Departments

The educational services department is part of Computervision's Customer Service Division, which also contains the documentation, hardware support, software support, Federal services, logistics, and national accounts groups.⁴ That organization reflects the company's philosophy that, once a system has been sold, the departments of the service division are responsible for providing all necessary customer services — including training, documentation, maintenance, and software and hardware diagnostic support. The director of training reports directly to the vice president of the North American Service Division. Reporting to the training director are the managers of the four training centers, the documentation manager, and the manager of media services. The following organization chart shows the horizontal nature of the service division:

4. The sales division is parallel to the customer services division. While there is a great deal of interaction between the two divisions, they are organized separately.

While there are few formal working relationships between the training department and departments outside the service division, there is a great deal of informal communication and cooperation. Temporary formal relationships are established, however, when training is developed for a new product. For example, four instructors are now working with the hardware and software development groups on the analytic processing unit (the new 32-bit central processing computer) and the CADDIS 4X software to determine training requirements for the new products. Within the service division, there is a great deal of interaction. The service division also provides the following support services to customers, many of which are training-related:

- o The Response Center is the nucleus of a network of support groups established to help customers solve hardware, software, or systems operations problems. Customers are provided with an 800 telephone number and can use it to call the response center for any type of systems problem. The response center personnel (who work in shifts from 7 a.m. to midnight Eastern time) route hardware problems to the communications center or remote diagnostics center and send software problems to the applications support center (see below). Customers who believe that their problem is a training-related problem due to lack of expertise in operating the system may also call the training department directly.
- o The Communications Center contains monitoring equipment which enables Computervision staff to locate where a hardware problem exists when Computervision systems are networked to other computers via telephone lines. They can determine whether the problem exists in the Computervision systems, in the phone lines themselves, or in other

systems to which the Computervision may be linked. If the problem is with the Computervision system, it is passed along to the remote diagnostics center or dispatched to a district office field engineer, who can then make a maintenance call to the customer site.

- o The Remote Diagnostics Center is used by customers who have purchased a diagnostic aid -- a modem that connects the central processing unit to the Woburn center and enables Computervision support staff to perform remote diagnostics to determine precisely where the hardware fault exists and what is causing it. The diagnostic aid reduces the amount of time required for the field engineer to repair the problem. If a replacement part is required, for example, the field engineer is informed by the remote diagnostics center which parts to bring with him to the customer site.
- o The Application Support Center helps customers to solve software problems -- many of which turn out to be operator errors rather than actual bugs in the software. The applications engineers in the support center recreate the customer's design on their own terminals and duplicate the customer's problem to aid in discovering whether the fault lies in the software or in an operator error.
- o Applications Engineers who work in the field also become directly involved in training, although not the formal type of classroom/lab training provided by the training department. Computervision's optional "full-service maintenance" contract provides 2 to 4 weeks of onsite applications support for the first 2 years after purchase. That means

that the customer may request that an applications engineer visit his plant after the formal training has been completed and the systems are installed to give advice on how to use the system most effectively for applications specific to the customer's operations. In these circumstances, the applications engineer often delivers one-on-one applications training to the customer's lead-operator. In most instances, the lead-operator will have attended the formal training courses where he or she would have learned how to operate the system to create general-application designs -- printed circuit boards, for example. The application engineer would then provide followup instruction on how to adapt the system's capabilities to the specific type and configuration of circuit boards produced by the customer-company.

- o Productivity Specialists conduct annual productivity reviews for one specific application (chosen by the customer) at the customer's site. The productivity reviews focus on the organization, utilization, training environment, and workflow that contribute to increasing the productivity level at the customer's installation. At the end of the review, the productivity specialist provides the customer with a written report suggesting ways to increase productivity through additional training, software or hardware enhancements, or changes of method.
- o Media Services produces and distributes videotapes describing hardware and software features, self-study audio/print training packages, and training packages designed for use by in-house instructors. The self-study course packages -- covering: 1) introduction to CADDS 3 operation;

2) introduction to CADDs & mechanical design operation; 3) CADDs & basic schematic and printed circuit design; 4) basic dynamic menuing (how to create system menus for individual applications); and 5) plotting -- are not intended to replace formal training. They are, rather, to be used prior to formal training as introductory courses and after the training as refresher courses.

North American Service employs approximately 600 people, 400 of whom work in the field as applications engineers, hardware engineers, and field engineers. The remaining 200 work in educational services, Federal services, logistics, and national accounts.

Goals and Philosophy of Customer Training

Computervision customer training operates on the philosophy that effective use of the systems requires a well-thought-out training plan designed to establish both broad and in-depth expertise within the customer's organization in order to take account of variables like employee turnover, absence, and tight production schedules. The educational services department, therefore, encourages customers to construct long-range training plans to meet their specific needs. Educational services' publications and staff members help the customers to: 1) take inventory of their own training needs and resources by identifying which personnel need training, making sure that practice time on the in-house terminals is available after the formal training, and identifying in-house personnel to be responsible for coordinating the training; 2) define individualized training strategies by planning in advance the training sequence required for each type of trainee (managers, supervisors, and system users); and 3) generate a training calendar

to make sure that the proper people are trained at the proper times (see pp. 9-10 for more details on the training sequence).

The primary objective of the educational services department is to support the customer by helping him or her to make the best and most productive use of the system. The training department therefore encourages the customer to be aware of the informal training options provided by the applications engineers, productivity specialists, media services and other groups in the services division and to take advantage of the training support they can provide. Goals and objectives specifically related to the training itself are discussed below.

Educational Services Staff

In addition to the training director, 4 training managers (1 in each training center), and 33 customer training instructors, the educational services department employs internal trainers, media services (i.e., audiovisual) specialists, and documentation specialists. The documentation group is responsible for operations and maintenance manuals and other technical publications. The training manuals are written by five of the instructors, who spend 50 percent of their time on course-and-materials development and 50 percent delivering training courses.

The majority of the instructors have either of two types of background experience: vocational education instruction in drafting or design, or professional experience in the various applications covered in the training courses. The usual procedure is to hire people with subject matter expertise in mechanical design, printed circuit board design, or the other applications fields and to put them through a 3- to 4-month internal training program on

systems use and training methods. Once the new instructors are comfortable with the material, they begin to teach the courses with backup support by an experienced trainer. As they grow more comfortable in the classroom and laboratory, they then begin to conduct the classes on their own. After 6 to 9 months, they are ready to deliver training onsite at a customer's plant with no backup.

Facilities and Equipment

Approximately 90 percent of the customer training courses are delivered at the four customer training centers; the remainder is delivered by special arrangement at the customers' plants. The national training center, just outside of Boston in Woburn, Mass., has the largest volume of training; the Los Angeles center has the next largest volume, followed by the Chicago and the Dallas centers. All of the centers have both classrooms and laboratories dedicated to training. The Woburn center has 10 classrooms and 5 laboratories, containing a total of 40 terminals.

Contractual Arrangements with Customers/Training Costs

Customers receive one training credit for every \$70,000 worth of hardware and/or software purchased. One training credit is equal to 1 week of training at a ComputerVision training center for one student.⁵ The average customer, therefore, who purchases a \$500,000 system receives approximately 7 weeks of free training. In addition, customers who purchase a full-service contract

5. Training credits may not be used for audio/visual products, documentation, or onsite training courses. The credits are good for 2 years from the date of purchase.

receive a 20-percent discount from cost for training beyond that covered by the credits. Basic and advanced training for systems users is \$800 per week for each student. CADDS programmer training in MACRO languages is also \$800, while FORTRAN graphics systems programmer training is priced at \$1,100 per week. A special 2-week "train the CAD/CAM trainer" course for in-house instructors sells for \$2,000 per student. Training at the customer's site is available for \$5,000 plus expenses per instructor/week.

Training Delivery

Computervision encourages customers to take a systematic approach to training--beginning with an "executive manager's overview," a 2 1/2-day seminar that provides a history of CAD/CAM, an overview of possible applications, and addresses management considerations for making the most effective use of the system. In addition, Computervision's Catalogue of Educational Services contains flow diagrams to aid managers in planning a training sequence for their employees. The flow diagrams recommend training sequences for managers, operators, and others who will interact with the system. Each sequence begins by specifying the job title of the potential trainee -- systems manager, mechanical designer, mechanical detailer, system programmer, electrical drafter, etc. -- and outlines the suggested progression from basic training, through a specified length of system experience on the job, to advanced training at a Computervision training center or at the customer's plant.

Overview of Training Courses

Computervision offers six categories of courses, defined by subject matter, which are further broken down by software type (CADDS 2, 3, or 4) and by the occupational category of the trainee. Following is a brief listing of the six categories and the types of courses offered in each.

- o General Interest Training Courses. General interest courses are provided for managers responsible for: 1) general systems installation and management; 2) technical administration of daily systems operations; and 3) technical administration of a networked system. Also included in the 'general interest' category is a course to train experienced CADDS 3 users to operate a system with CADDS 4 software, and the "train the CAD/CAM trainer" course mentioned above. The train-the-trainer course is an extensive 2-week course that teaches participants how to plan, design, and implement an effective Computervision training course. Potential trainers also receive instruction on learning theory, presentation skills, and use of instructional materials.

- o Mechanical Design Courses. Two 1-week courses (one basic and one advanced) are offered for designers, drafters, and their respective supervisors who will be using the CADDS 3 mechanical design software package. Four courses are available for CADDS 4 users. A 2-week basic mechanical design course serves both detailers and designers. Detailers attend only the first week of the course, which covers 2-dimensional interactive drafting, while the designers stay on for an additional week to learn 3-dimensional modeling techniques. Detailers who have had the basic course and 60 hours of system experience can then return to take an

advanced course called mechanical detailing, while designers who have taken both weeks of the basic course should have 120 hours of system time before returning to take the advanced mechanical design course. The fourth CADDS 4 mechanical course is a special applications training program for architectural designers and facilities planners.

- o Programing Courses include graphics systems programing courses designed to introduce experienced FORTRAN programmers to CADDS programing utilities and software (two such courses are offered; one on CADDS 3 and one on CADDS 4). Two macro language programing courses (one for CADDS 3; one for CADDS 4) teach experienced Computervision users to design, code, and debug programs in various macro languages. Another programing course trains FORTRAN programmers to develop post-processor programs for numerical control machines.⁶
- o Printed Circuit/Electrical Schematics (PC/ES) courses are offered to CADDS 2, 3, and 4 users. Basic and advanced PC/ES courses are available for electrical drafters and designers on both CADDS 3 and CADDS 4 systems. Basic and advanced wiring diagram courses are also offered for CADDS 3 and CADDS 4 users who create ladder diagrams and other electrical schematics. In additon, two CADDS 2 courses instruct designers and fabricators of integrated circuits in the techniques required to use CADDS 2 as an integrated circuit design tool.

6. The Computervision system is FORTRAN-based.

- o Piping courses are offered to users of CADDS 3 and 4. Basic piping courses teach piping drafters and designers how to generate piping and instrumentation diagrams and other piping features for process plant design. Advanced piping courses are aimed at piping designers, software engineers, or programmers who will be using the system to set up bill-of-materials formats and other specialized system text files to be used by piping drafters and designers.

- o Numerical Control (NC) Courses. One CADDS 3 course trains experienced NC programmers who have taken the Computervision mechanical design course to use the NC application package to create tool path designs for use in numerical control machines. Three CADDS 4 NC courses are offered. The first, in essence, combines the CADDS 4 mechanical design course with NC part programming design instruction to create a 2-week course for experienced NC programmers who have not previously used Computervision systems. Two advanced NC design courses are also available for CADDS 4 users.

Customized Training Courses

Computervision instructors will, on request, customize training courses to the customers' specific needs and applications. At present, 10 instructors are delivering an extensive series of tailored training courses for the U.S. Navy. The training -- part of a \$64 million equipment contract that began as a purchase by the naval laboratories and has since increased to include shipyards and other naval installations -- is still being defined and expanded and is anticipated to result in 175 to 350 classes (8 students per class) onsite at various installations across the country. To date, 33 separate,

customized courses -- covering basic, intermediate, advanced, and "update" training for supervisors, applications personnel, designers, and operators -- have been developed in mechanical design, printed circuit board design, numerical control, and other areas.

Course Length

Course length ranges from the 2-hour executive managers' overview to the 2-week "train-the-trainers" and CADDS 4 basic courses for designers. All operations courses for CADDS 2 and 3 are 1 week in length, except for the CADDS 3 architectural design course. As a general rule, CADDS 4 basic courses are 2 weeks in length, while CADDS 4 advanced courses are 1 week long. The expansion to 2 weeks for CADDS 4 courses provides the trainees with more time to absorb basic systems operating techniques and to learn the additional commands and techniques necessary to use CADDS 4 software, which has more capabilities than CADDS 3. In effect, the expansion was a response to customer requests. While developing the CADDS 4 courses, the manager of the national training center conducted an extensive telephone survey of Computervision customers -- explaining to them the differences between CADDS 3 and CADDS 4 software and asking their response to delivering the training in either a 1-week or 2-week format. The customers advised the company to go to a 2-week format for CADDS 4 basic training. The construction of the 2-week CADDS 4 courses -- whereby the information and laboratory practice intended for both detailers and designers are presented in the first week, while the second week is focused on the needs of designers only -- was also done in response to customer demands to provide training oriented to the particular needs of various classes of users.

Occupational Categories and Prerequisite Skill Requirements of Trainees

Computervision basic training courses are designed for managers, designers, drafters, and detailers (each of whom take the Computervision course consistent with their principal work responsibilities). The "overview of training courses" section on pages 10 to 12 lists the occupational categories of the trainees most likely to take specific courses. The following list summarizes the occupational categories of the majority of Computervision trainees:

- o Mechanical designers and detailers
- o Printed circuit designers
- o Electrical drafters and designers
- o Architects and illustrators
- o Numerical control programmers who create geometry and tool paths
- o Integrated circuit designers
- o Piping designers and drafters
- o Programers
- o Department managers
- o Company executives

Prerequisites suggested for advanced courses include both the basic course in the trainee's discipline or job category plus specified amounts of system experience.

Class Size

Class size ranges from a minimum of 4 to a maximum of 10 students. If fewer than four students register for a scheduled class, the class is usually

cancelled and the students are slotted into the next available class. Cancellation occurs relatively infrequently.

Training Methods and Materials

The goal of all of the basic user's courses is to train professionals who are already knowledgeable in their design, drafting, or detailing trades to use the computerized work station as a tool to perform their jobs. Two major objectives of the first 2 days of training are: 1) to overcome "computer anxiety"; and 2) to overcome the students' sense of being "intimidated" by what seems, at that stage, to be a vast amount of knowledge required before they can insert the first piece of geometry into the system. Instructors address computer anxiety during the first class meeting, explaining to the students that no previous knowledge of computers is required and that they are not dealing directly with the computer itself but with the interactive workstation, which replaces the drafting table. Users communicate with the system via a command language that is based on normal English usage and made up of verb + noun + modifier strings.⁷ Both the command language syntax and the instructors' explanations of precisely how the students will be interacting with the workstation are designed to reduce computer anxiety -- and, in the vast majority of cases, actually do so. The students' feelings of being intimidated by the amount of information required to operate the system usually work themselves out by the third day, by which time they have had ample opportunity to work at the terminals to execute the various commands required for beginning operation.

7. Case study No. 9, Glendale CAD/CAM operators training program (p. 15), contains a detailed description of Computervision command language.

All Computervision user's courses are formally structured into a 50-percent classroom/50-percent laboratory format with each daily class divided up into four segments — 2 hours of classroom instruction, followed by 2 hours of laboratory practice in the morning and the same again in the afternoon. In actuality, most students complete more than the 4 hours a day allotted to laboratory practice, since most stay on in the early evening to work at the terminals. The classroom instruction consists of lectures and class discussion. There are no demonstrations during the classroom segments because the instructors have not found a way to display the workstation screen so that it could be seen by the entire class. (At one time, instructors tried to use large-screen television displays for demonstration purposes, but abandoned it because there was too much distortion to allow the class to see the demonstration clearly.) During the laboratory segments, the students work in teams — two to a terminal, one operating the keyboard and the other operating the menu. The partners switch operations once an hour, and new student teams are formed each day to give each trainee the benefit of working with a new partner and to make sure that a weak partner is not consistently intimidated by an overly strong partner.

The goal of the advanced classes is to increase the students' ability to make effective use of the system and, hence, their productivity. It should be noted that — aside from the operator's classes for system managers, who are not expected to use the systems on a regular basis but who must know how they are used in order to manage the workflow — all Computervision user courses focus on a particular application, such as mechanical design or printed circuit board design. Unlike a number of other CAD/CAM vendors, Computervision does not offer instructor-delivered user courses focusing on system operations alone. According to Computervision trainers, "it is unwise

to come up with a generic course that transcends application, because at various times during the course you would lose a large part of your audience if the course is not focused on the application required by all of the students."

In contrast to the specific-application-oriented lecture classes, some of the self-study packages sold by Computervision do focus on basic operations for CADDS 2, 3, and 4 systems. Computervision training representatives stress, however, that the self-study packages are not meant to replace instructor-delivered courses, but to serve as a preview and review for students who have attended formal courses, delivered either by Computervision instructors or customer-company trainers.

All trainees receive operator's manuals geared to the topic of their course. In addition to the manuals, students receive Operator Preventive Maintenance Guides, and quick reference guides to the system. (Computervision's "systems approach" to training is discussed in sec. IV.)

Evaluation and Followup

Evaluation of Trainees

Daily "reviews" -- in the form of take-home quizzes -- are given in each course. The students are expected to use their manuals and their class notes to complete the reviews, which are discussed in class the next morning and are self-graded by the students. On the final day of class, students complete a "major review" in the classroom, again using their manuals and notes. Following the review, the instructor and students discuss the questions and the students' answers, but the reviews themselves are not graded or

collected. Normally, the instructor can tell from the students' answers what they have missed and what needs reinforcing in the last day's session. Written evaluations, completed by the instructor, are kept on file for each student but are not sent to their employers. Employers may, however, call the instructor to get information on the performance of their employees.

Evaluation by Trainees of the Course and the Instructor

Trainees complete written evaluations of the instructor, the course, the atmosphere, the Computervision system on which they trained, and the material presented. The evaluations are then reviewed by the training manager -- primarily to see whether, in the students' opinion, the course objectives had been met.

Followup

While the educational services department does not conduct formal followup procedures, trainees are informed that they may feel free to call the instructor at any time after the completion of the course. According to Computervision representatives, formal followup by the training department is rarely necessary because of the close involvement of the CAD/CAM firm with its customers, the numerous support services provided by the other sections of the service division, and the fact that 25 to 30 percent of the trainees return for advanced training.

Users' Meetings

Computervision sponsors annual users' conferences, which also help the firm to follow up on training and other issues. The users' conferences give the customers an opportunity to talk to each other; to discuss common problems, applications, and needs; and to present questions, suggestions for new directions, and requests for additional service, software updates, new applications needs, and a variety of other items to Computervision representatives. Formal papers on a number of topics are presented -- from applications and techniques devised by customers; to reports on individual networking attempts and system management techniques, to training techniques. These papers are collected, compiled, printed, and bound by Computervision and are available for purchase by the users. In addition to the Computervision-sponsored user meetings, the customers themselves hold annual regional meetings, and customers involved in similar applications -- aerospace, or shipbuilding, or electronics, for example -- hold individually organized meetings throughout the year.

Results

Like many customer training organizations, the Computervision educational services department keeps attendance records by "student/weeks"⁸ rather than by head-count in the classes. Because the courses are variable in length and because many students return to take advanced classes, this method of recordkeeping is considered to be the most accurate reflection of the amount of training actually delivered. In 1982, the educational services department

8. A "student/week" equals 1 week of training for one student.

delivered 4,500 student/weeks of training. The number of student/weeks anticipated for 1983 is 6,500 (including the onsite training delivered to the Navy).

The naval contract itself produced some unanticipated results for Computervision and its commercial customers. One of the formal requirements in the Navy contract was that Computervision rewrite its user documentation to make it more user-friendly and more readable.⁹ Because the naval contract, therefore, required the rewriting of the majority of the documentation for most Computervision application software, the company used the requirement as an opportunity to rewrite its commercial documentation as well so that it is more reflective of user needs and more understandable to the average user. Another beneficial result to Computervision was that the Navy contract generated increased interest in the company's products and services on the part of top-level industrial managers. This gave the company a chance to speak to corporate executives and make them aware of the requirements -- including training, practice time, service, and maintenance -- for effective system use. That was especially beneficial because, all too often, top-level executives are unaware of what the systems can do, how long it takes for users to become fully productive (usually 9 months), and the amount of training and preparation required for full productivity.

9. This requirement was literally written into the contract as "the no-gobbledygook-clause."

II. GCA

The GCA Corp. was established in 1958 as a geophysical research organization. By the early 'sixties, the corporation had become product-oriented, and in 1964, what was once the Geophysics Corp. of America became, simply, GCA. In 1974, GCA employed fewer than 90 people in both manufacturing and service; today, it employs over 1,000 people in those functions and has over 100 employees in field service alone. Its product line, too, has expanded and diversified.

GCA is, perhaps, best known as a producer of automated semiconductor capital equipment used in the manufacture of integrated circuits. In 1981, the corporation formed an Industrial Systems Group which now produces extended-reach robots, remote-handling and large-scale robotic systems,¹⁰ and (through a joint venture with Dainichi Kiko of Japan) markets robots for assembly, machine tool loading and unloading, and material transfer. GCA also markets vacuum and controlled-atmosphere furnaces for processing metals, superalloys, and ceramics. In the area of scientific and analytical equipment, GCA supplies ovens, incubators, vacuum pumps, refrigerators, and other laboratory products to laboratories involved in the life sciences, energy, and electronics. It also produces petroleum equipment for measuring the physical properties of oil to improve yield -- including a microprocessor-controlled system for testing fuel composition and analyzers that monitor vapor pressure for gasoline blending. In addition, GCA provides environmental services focusing primarily on the cleanup of hazardous waste in dump sites and in drinking water supplies.

10. The large-scale and remote-handling robotic systems are designed and produced by BCA/PaR Systems, a wholly-owned subsidiary formed through GCA's acquisition of PaR (programmed and remote) Systems of St. Paul, Minn.

GCA EDUCATIONAL SERVICES: CUSTOMER TRAINING OVERVIEW

The vast majority of GCA customer training courses focus on operation, evaluation, processing, and maintenance techniques associated with its line of semiconductor equipment. Robotics training is, at present, conducted from the Minnesota-based PaR Systems Division as an essentially separate activity. The present study is confined to the semiconductor equipment training delivered at GCA training centers in Boston, San Francisco, and Dallas or onsite at customers' plants.

Semiconductor Production Equipment

GCA offers training courses on four microlithographic production systems: 1) the DSW (direct-step-on-the-wafer) Wafer Stepper® system; 2) the Wafertrac® automated silicon wafer processing system, 3) the Model 3600/3600F Pattern Generator, which generates master patterns of integrated circuits, and 4) the Model 3696 Photorepeater®, used in photomask fabrication. All of these systems are briefly described in the following paragraphs, special attention being given to the DSW and the Wafertrac as the two systems most currently in demand by the semiconductor industry.

The DSW Wafer Stepper system first appeared on the market in 1977 and is now the industry standard for production equipment used in the manufacture of memory and logic circuits. In effect, the DSW reduces a master pattern of a circuit 5 or 10 times and then projects and prints that image many times directly onto a silicon wafer in precise rows and columns to form one level of an integrated circuit.¹¹ The printing of the circuit in precise arrays on the wafer is called "stepping." The stepping process is performed by a motions

system controlled by a laser returing system. The motions system moves the wafer from one exposure position to another under the optical system lens. The DSW system has a number of automatic features, some of them optional. "Autofocus," a standard system feature, is an automatic focusing system that maintains the sharp images created by high resolution optics throughout the exposure process. "Automatic wafer handling" is an optional feature that automatically loads, prealigns, and unloads the wafers. Another optional feature is the "automatic wafer alignment" system, which precisely aligns the wafer under the lens and automatically initiates the "expose" command to the system software. Yet another optional feature is the automatic reticle changer/aligner. The reticle is a glass plate containing the master circuit pattern etched in chrome. The DSW reduces and exposes the pattern etched on the reticle onto the silicon wafers. The reticle changer/aligner automatically selects reticles from a cassette attached to the DSW's optical column, transports them to a platen in the optical column, and automatically aligns them. Masking aperture blades selectively mask off border areas on the reticles. The computer control for the DSW system operates under general direction from a Digital Equipment Corp. computer. The system has an operator's console containing a video keyboard terminal for job setup and system control, a dual floppy disk drive, a TV viewing monitor for wafer alignment, buttons controlling routine functions, and other features. The GCA-designed system software has two standard modes of control: an "operator's mode" involving minimal interaction between the operator and the computer; and a "supervisor's mode" used by engineers to program the requirements and specifications of a particular job. The GCA training

11. The product descriptions on pp. 25-28 are adapted from GCA marketing and technical publications.

department offers operations and maintenance courses on the basic DSW system and advanced maintenance courses covering a number of the automated features described above. DSW system training accounts for almost three-quarters of the customer-training courses offered by GCA.

Another semiconductor product, which can be linked with the DSW system, is an automatic wafer processing system called Wafertac. Wafertac automatically cleans, coats, bakes, develops, and stores the silicon wafers. When integrated with the DSW system, it enables wafer processing and photolithographic image printing to be done without manual intervention. GCA supplies the following explanation of that integrated process: "After raw wafers are loaded into Wafertac, they go through a series of process steps during which they are scrubbed and coated with light-sensitive material (called photoresist) and then baked. They are then transferred automatically to a holding station from which they are dispatched via the interface to the DSW for image exposure and stepping. After exposure, each wafer is automatically returned to Wafertac for development of the micro-imagery. The developed wafer is then stored." Customer courses are provided on Wafertac operations and maintenance.

The DSW and the Wafertac are the two systems with the highest volume of sales and, consequently, of training activity. GCA does, however, produce two other semiconductor systems which are supported by one training course apiece. The pattern generator generates the integrated circuit master patterns on plates that ultimately become the reticles used in the DSW system. The Pattern Generator creates a picture of a circuit which is 100 times larger than the image that appears on the silicon wafer. That image is then reduced 10 times by another GCA product, a microreduction camera called a

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photorepeater, and produced on photoresist plates. The plates, after etching, become the reticles containing the master pattern which is reduced another 10 times in the DSW system process to become the image on the wafer.

Customer Training Department: Past Development and Current Organization

GCA did not provide formal customer training until 1978, when DSW system sales began to grow. Neither did it have a formal field service department prior to 1977, when the DSW was first introduced. In the early and midseventies, the sales volume was low enough and the company was small enough for the phototest department, whose prime responsibility was in-depth testing and quality assurance of systems to be delivered to customers, to also be responsible for installation and customer support after delivery. In 1977, a Field Service Department was created to meet the growing need for a separate customer service group to install and maintain the increased numbers of systems in the field.

The first formal training courses were developed in response to customer requests for maintenance training on the new DSW system. Operations training was originally delivered informally to the customers' technicians during their "application visits" to GCA -- visits during which the technicians were given demonstrations of the equipment and would determine its applicability to their own manufacturing processes. Formal training began when a number of individual customers who wanted an in-house maintenance capability requested that training courses be built into their equipment contracts.

Initial Training Efforts

GCA's first customer training courses were relatively informal affairs, scheduled irregularly to meet individual customers' needs and delivered by GCA technical employees with little or no training experience. GCA programmers, engineers, and technical writers would lecture on programming and operations theory, and a member of the DSW research and development group delivered the hands-on operation and alignment-test training. As the need for maintenance grew — based on increased customer requests for basic and advanced levels of maintenance instruction — the need for a formal customer training department became apparent. At the same time, the increase in sales from a few units a month in 1977 to significantly larger numbers of units a month in 1978-79 resulted in the need for formal training for the new field representatives who were hired to provide installation and support for the systems in the customers' plants.

First Formal Training Groups

By 1979, then, GCA had two training groups: a customer training group and a field service representative training group. By January 1980, a separate service division had been formed containing field services and field service training, customer training, and a "technical support group" made up of topnotch service representatives who were assigned to track product development projects and act as liaison between engineering R&D, the trainers, and the field representatives. In June 1982, a further step was taken to coordinate training by combining the customer and the field representative training into one department within the service division.

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Current Training Organization

A single training department now provides courses for both the field representatives and the customers. The content of the customer and field representative instruction is identical up to a point, but the field service personnel normally receive more in-depth training than that contracted for by most customers. The manager of the training department now reports to the director of technical services, who in turn reports to the general manager of the service division. Also reporting to the director of technical services is the technical support manager, who is responsible for the technical support group.

The various groups in the service division aid each other in a number of ways. The support supplied by the training department to the field service department needs no further elaboration. Field service representatives support training by providing information about maintenance and troubleshooting techniques they have developed on the job to the training department, which then incorporates the best of those into the courses and training manuals. The technical support group aids the field service representatives by serving as a high-level technical information and troubleshooting team for particularly difficult customer problems. In addition, the members of the technical support group regularly interact with the training department staff to provide technical information and assistance in the development of new courses. (When a course is delivered for the first time, a technical support staff member will sit in on the course as a backup to the instructor to make sure that all the necessary systems information is covered.)

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Goals and Philosophy of Training

The primary goal of GCA customer training is to "maximize equipment uptime" (currently averaging 90 to 95 percent) and to augment the customer's in-house resources for operating, diagnosing, and maintaining the equipment. The majority of GCA's customers take advantage of its "guaranteed maintenance program," which provides maintenance support services within 2 hours 90 percent of the time and provides a 100 percent guarantee of service within 24 hours. Thus, a number of GCA customers prefer to train their employees to perform minor maintenance tasks and rely on the GCA field service representatives for major maintenance problems. Approximately 5 percent of GCA customers prefer to develop their own in-house maintenance capability to as high a level as possible. The philosophy of the training department is to meet the customer's stated training needs at whatever level of sophistication is requested.

Training Department Staff

The department manager got his original training experience in 1973, when he served as the "hands-on" trainer for the initial GCA training courses described above. Prior to that, he was in the phototest and field service departments and the DSW system R&D group. The five instructors in the Boston area training center and the one permanent instructor in the San Francisco area center have a variety of backgrounds.¹² Some have manufacturing backgrounds in GCA factories; some were previously in the phototest

12. Training in the Dallas training center is delivered by instructors sent out from either Massachusetts or California. At the moment, very little training is needed in the Dallas area.

department; and some were hired directly after graduating from 4-year colleges with electrical engineering degrees or from 2-year technical colleges as electronic technicians. Almost all have some background in photography as well. Two of the current instructors had previous teaching experience -- both as trainers in armed services courses on such topics as radar repair, guidance system alignment, and electronic chassis repair.¹³

Like the field service technicians, GCA trainers must combine a knowledge of, or at least an interest in, photography or photographic techniques with experience in and/or knowledge of electrical maintenance plus the skills and dexterity of a precision mechanic. In addition to the combination of technical knowledge and manual dexterity, GCA trainers must also have the ability to communicate clearly and, because the customers must be assured that information about their proprietary chipmaking processes is not revealed to their competitors, must (to use old-fashioned words in a new-fangled setting) be "trustworthy" and be able to convince customers of their "integrity."

Facilities and Equipment

Most customer and field representative training is conducted at GCA's Boston area training center, adjoining GCA's newest manufacturing plant in Andover, Mass. The Andover facility has four formal classrooms, a combination classroom/laboratory for Wafertrac system training, and five additional laboratories for hands-on training on the DSW, pattern generator, and

13. According to the training manager, technicians trained in the armed services make excellent field service representatives, and armed services instructors, in his experience, are excellent trainers. Many types of precision-technician work done in the armed services, he says, are similar in nature to that done at GCA.

photorepeater systems. The Dallas and San Francisco area centers have two classrooms and two laboratories apiece.

The Andover facility has four DSW systems dedicated to training (some kept in environmental chambers and used for demonstrations and for operation training and others left in the open for maintenance training); a Wafertrac system; and approximately \$200,000 worth of test equipment, including oscilloscopes, volt meters, and gauge blocks. Because there are relatively few pattern generators either in production or in customer plants, the training department does not have a pattern generator of its own and must make arrangements for borrowing one from the manufacturing division when classes are scheduled on that system. This arrangement occasionally creates logistical problems for the training department. Those problems are discussed in sec. IV.¹⁴

Contractual Arrangements with Customers/Training Costs

When the customers sign an equipment-purchase contract, they receive a certain number of training credits based on the type of equipment purchased. Training credits are worth \$500 apiece and are valid for 1 year after the shipping date. The DSW systems carry five training credits (or the equivalent of \$2,500 of training) for each system purchased. Four training credits are received for each pattern generator or photorepeater purchased, and the Wafertrac carries two credits. Training costs vary according to the length and complexity of the course. The basic operation and evaluation course on

14. By using a conversion kit, the DSW can be made to operate like a photorepeater. The training department, therefore, uses DSWs to train photorepeater customers.

the DSW, for example, is a 5-day course which costs \$1,000 per trainee. The cost of sending one trainee to the 10-day basic DSW maintenance is \$2,500. Thus, the customer who sends one operations trainee and one maintenance trainee to receive DSW training would, because of the \$2,500 training credit, actually pay only \$1,000 for the 3 weeks of combined operations and maintenance training.

In addition to the training credits, customers receive volume discounts when they register more than three trainees at the same time for the same course. (Students, however, have the flexibility to attend the course at different times.) Similar discount savings are offered to DSW customers who register more than one employee for both the operations and maintenance courses delivered at the Andover facility.

If a customer wishes to go beyond basic operations and maintenance on the DSW, five advanced maintenance courses are provided on the various optional and standard system features described on page 20. A total training package for one trainee covering operations plus basic and advanced maintenance on a DSW with all of the optional features (seven training courses lasting from 1 to 3 weeks apiece) costs \$8,250 (\$10,750 minus the training credit of \$2,500). Customers who take advantage of the discounts by, for example, registering six trainees for the two basic courses, save 43 percent of the regular training costs. Similar discounts are offered to customers who register more than one employee for four advanced maintenance courses on the DSW.¹⁵

15. All training course costs are subject to change.

The training discounts serve two major functions: first, they aid the customer faced with sizeable training costs; and second, they help GCA by motivating employers to train teams of employees, thus providing proper support for the systems and aiding the GCA training department in scheduling courses (since at least three trainees must be registered for a scheduled class to be delivered).

Training Delivery

The training department offers regularly scheduled courses at the Andover training center on operations and basic (level I) and advanced (level II) maintenance for the four major semiconductor production systems produced by GCA. Whereas the Andover training center offers 13 regularly scheduled courses (seven of them on the DSW), the San Francisco area center offers seven courses, and the Dallas center offers two. Customers may also contract for training delivered at their own plants. The number of customers choosing to have in-plant training is growing -- up from 5 percent in 1981 to 20 percent in 1982.

Overview of Training Courses

Two basic operations minicourses are offered: one on the Wafertrac and one on the DSW. The intent of those two courses is to train operators to perform daily systems operations tasks under minimal supervision. These courses are not listed in the schedule and are usually delivered at the customers plants.

Basic DSW courses include system operation and standard system evaluation, and level I maintenance, which prepares technicians to diagnose

minor maintenance situations and to perform routine maintenance duties (such as replacing faulty circuit boards). A series of level II DSW maintenance courses cover in-depth maintenance of the system's major standard and optional features, such as the optical peripherals (a high pressure mercury arc lamp light source and two alignment microscopes), the automatic wafer handler, and the automatic wafer aligner (see p. 26). Another level II maintenance course offers an in-depth study of the servo drive system that controls the motions of the precision-machined stage that holds the wafers during the wafer stepping process.

Other scheduled courses include level I maintenance courses on the photorepeater and the pattern generator (also covering operation and system evaluation); operations and maintenance of the Wafertrac system; and a level II maintenance course covering configuration, adjustments, and diagnostics for the automatic plate changer (an optional feature on both the photorepeater and the pattern generator).

Customized Training Courses

At the customer's request, GCA provides custom-tailored training programs, usually for large-volume buyers who require a large amount of training and/or have ordered systems with special configurations or applications. Sometimes in-plant training focused on the customer's specific application is delivered in addition to instruction at the GCA training center.

Course Length

Courses range in length from the 2-day minicourses on the operation of the DSW and the Wafertrac systems to a 3-week course covering the operations, diagnostic evaluation, and maintenance of the pattern generator. The DSW basic maintenance course — which covers a variety of mechanical, electronic, software, and optical maintenance requirements — is 2 weeks in length. The other courses on the DSW and other systems last for 1 week.

Occupational Categories and Prerequisite Skill Requirements of Trainees

Occupational categories of trainees attending GCA courses include electro-mechanical technicians, line supervisors, lead operators, and engineers. For the most part, engineers and supervisors take the level I operations and maintenance courses to be able to watch for and identify problems. Electro-mechanical technicians take both the level I and level II courses. According to the GCA training manager, system operators rarely are sent by the customers to take the full-length operations courses. The usual customer procedure is to send the lead operator to a GCA training center to take the operations course. The lead operator will then return to the plant to teach daily operational procedures to the lower-level operators, who work under supervision by the lead operator. The training manager, however, has noted that the number of customers requesting minicourses for their operators is increasing.

GCA has had very few problems stemming from trainees not having the prerequisite electronics, mechanical, and photolithographic backgrounds to benefit from its training courses. GCA's customers, according to the training manager, are usually highly educated users and are well aware of the skills

required to operate and maintain the systems. Fewer than 5 percent of the trainees come to the courses unprepared.

Class Size

Class sizes range from three to six students. Aside from the uneconomical aspect of training less than three course attendees, GCA instructors have found that the "one-on-one or one-on-two" class is less productive than one delivered to a larger group. The interaction of a group environment, the additional questions asked by the other trainees, and the necessity of covering all the necessary information is reduced when only one or two students are present in a class. When more than three students enroll for Level II maintenance classes, the instructor makes sure that two pieces of equipment are available so that all of the trainees receive adequate hands-on practice. According to the training manager, a class of four students working on two systems produces the best training environment.

Training Methods and Materials

GCA training courses are approximately 50 percent lecture and discussion and approximately 50 percent hands-on laboratory practice. The basic approach taken by the instructors is to present the theory behind the operation or maintenance of a part or subsystem and to reinforce the lecture/discussion immediately by moving the class into the laboratory for hands-on practice. In the operations course, students get hands-on experience by bringing the system up from a cold start each day; operating the control system to load, align, and expose the wafers; and performing system evaluation tests. Approximately 10 percent of the time in the operations course is devoted to troubleshooting

exercises on startup and operating problems, or on "bugs" placed in the equipment by the instructor.

The maintenance courses operate on the same principle as the operations courses, except that more time is spent on troubleshooting. The progression of activities in maintenance courses is lecture, demonstration, operations or evaluation testing, and troubleshooting for each module. For example, in the "auto-focus" module of the DSW level I maintenance course, students first learn how the subsystem operates, see a demonstration of a smooth operation, and then practice operating it themselves. During the troubleshooting portion of the instruction, the trainers teach the students to use a systematic approach. The training technique used encourages a logical diagnostic and troubleshooting approach, from the system level through the subsystems, down to individual components. Trainees are encouraged to think the problem out before dismantling the system, to explain to the instructor and their team members where they think the problem exists, why it exists, and how they would go about correcting it before they actually attempt to do so. This not only motivates the trainees to think before they act, but it also gives each member of the team an opportunity to find out how another person would approach the problem.

The maintenance course normally includes two to three scheduled homework assignments. However, if a course is not progressing according to schedule (which most often happens in a "good" class where many questions are asked) trainees may be given additional homework assignments to enable them to get back on schedule.

Instructional materials include training manuals, videotapes, and video prints and slides. The training manuals are developed by the instructors and

training manager from operations and service manuals, teaching notes, field representative information, and customer suggestions from previous courses.

Evaluation, Certification, and Follow-up

Evaluation and Certification of Trainees

Trainees take a series of written and performance tests which are designed to show the instructor whether the student has taken the time to think problems through rather than jumping at the first seemingly right answer. This is done in the performance testing by, for example, occasionally placing a bug in a part of the system covered 2 or 3 days previously; some students tend to focus immediately on the part just covered in the lecture, rather than proceeding in a logical manner.

Trainees receive a final evaluation based on the written and performance tests, mechanical ability, attendance, and other class participation factors. These evaluations are not sent back to the customer but are kept on file in case problems arise once the trainee returns to his or her home plant. The 98 percent of the students who perform adequately in both the hands-on and written tests receive certificates of completion.

Evaluation by Trainees of the Course and Instructor

The trainees fill out written evaluations on the last day of the course. The students are also encouraged to send in followup evaluations to the training department after they have had a chance to use their operations or maintenance skills at their home plants. The evaluations have been positive for the most part. The major problem mentioned by past students was

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the need for additional hands-on time in the operations course. The training department responded by limiting the class enrollment (which was 10 until recently) to 6 students in order to provide more equipment time for each trainee. A problem mentioned by approximately 20 percent of the level I maintenance trainees was more of a communications difficulty than a training problem. They complained that the level I course had not covered topics which, according to the training department, belonged in the level II courses. Instructors and the training manager have addressed this problem by clearly stating precisely what is covered in each level of maintenance training to both employers and trainees. No notable negative responses were received on the level II maintenance courses.

Followup

Formal followup has been limited to one survey, conducted last year, which produced results similar to those listed above under "Evaluation by Trainees." On the informal level, trainers respond to followup telephone calls from trainees requesting minor troubleshooting assistance or specific additional information once the class has been completed.

Results

In 1982, GCA trained approximately 250 customer employees. Training projections for 1983 include 400 or more anticipated registrations for operations and maintenance training on the DSW alone (this represents less than 400 trainees, since many are registered for multiple courses). The combined effects of the recession (during which orders for GCA equipment fell off) and time required for technicians with level I maintenance training to

progress to the stage where they can benefit from level II training has resulted in the cancellation of a number of level II maintenance courses for the first 6 months of 1983. GCA is, however, currently delivering a full schedule of training courses on the basic level. At the same time, equipment orders and deliveries have been increasing, so that the training manager believes that a significant amount of level II training will be delivered during the last two quarters of the year.

III. AUTOMATIX

Automatix, a small but growing robotics and vision systems firm, was founded in January 1980. Currently employing approximately 200 people, 60 percent of whom are in research and development, the firm has been growing at the rate of 300 percent a year in sales. Gross sales in 1982 were approximately \$8.2 million. Projected sales in 1983 range from \$16 to \$20 million, depending on market conditions and capital expenditures in industry.

Automatix produces three major products: 1) Robovision, a programmable arc welding robot system, 2) Cybervision, a robot assembly and processing system, and 3) Autovision, a programmable visual inspection system. The robots (all of them electric, d.c. drive models), cameras, and power supplies used in Automatix systems are purchased from manufacturers in the United States, Japan, and Germany. Automatix integrates the purchased equipment with its own control system (the AI 32 control processor) and writes its own operating and user-interface software. As a turnkey systems house, Automatix specializes in integrated systems packages tailored to the customer's specific application. Both the Cybervision assembly system and the Robovision arc welding system, for example, can be configured with and without artificial

vision; and both can be packaged with multiple arm configurations, custom tooling, and provisions for off-line programming. The Autovision visual inspection system can be used as the "eyes" for the robots or can stand alone and inspect the sort parts to help assure quality control.¹⁶

The company's headquarters, factory, R&D, and training facilities are all located in a single facility in Billerica, Mass. (just off the Boston area's route 128). The firm also operates a Detroit office, which primarily serves the automobile industry, and seven additional district sales offices in the United States. International distribution and sales are conducted through a Paris office, staffed by Automatix employees, and a distributing firm in Japan, which also handles a number of other American firms, including Computervision.

CUSTOMER TRAINING OVERVIEW

Automatix conducts monthly customer training courses on both the arc welding and the vision systems and four-times-yearly courses on the Cybervision assembly system. Like the company itself, the training department is small, flexible, and (at present) straining to keep pace with the growing number of sales. The current manager of training and communications was hired at the end of 1981 to coordinate: 1) training; and 2) press relations, marketing publications, and audiovisuals. Before that time, no formal

16. Automatix provides the following description of the visual inspection system's capabilities: "As randomly presented parts are viewed by the camera, at rates up to hundreds of parts per minute, they are measured and classified according to preprogramed characteristics such as area, perimeter, number of holes, hold area, center of gravity, and other similar parameters. The information extracted is then used to determine part completeness, make go/no-go decisions, adjust process variables, control robot devices, or perform a great number of other similar functions." (Product Bulletin)

training department existed, customer training being one among many responsibilities of one of the firm's field service representatives.

The training manager came from an administrative, teaching, and communications background, and was hired for his flexibility, energy, and communications skills. From the perspective of Automatix's upper management, the new training department had to be directed by someone with the ability to communicate, to develop training courses that could cover a sizable amount of complex material in a limited amount of time, and present that material clearly to a variety of customer employees — ranging from applications engineers to shop-floor operators. In the words of the manager of customer support, "you can hire all the technical people you want, but if you can't get the point across, you'll never get the customer trained."

The company's choice of an educator/communicator over a technical specialist was also based on its size and close-knit organization. In 1981, Automatix employed fewer than 100 people in its Boston area facility; the various departments — especially R&D, applications, field service, technical support, and sales — interacted with each other to design, produce, sell, and service Automatix systems. The new training manager was given free access to software, hardware, and applications specialists in all departments and was given the responsibility of "packaging" their technical knowledge and presenting it in a readily understandable format.

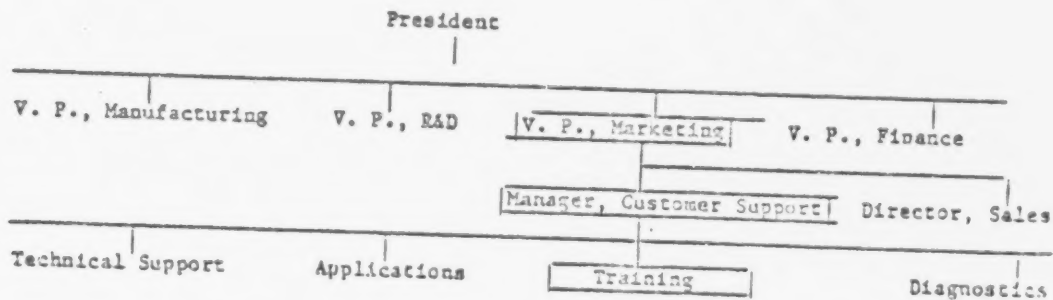
Customer Training Department: Past Development and Current Organization

When he was first hired, the training manager was a one-man department. He describes his function then, as now, as a coordinating one -- he, in essence, serves as a "broker" between the customer and the technical

specialists in various Automatix departments. At first, since there were no technical specialists specifically assigned to training, the training manager went through a break-in period during which he collected information about the systems from personnel throughout the company and used it to develop course structures and outlines. The actual training delivery was done by a team of Automatix employees coordinated by the training manager. The training manager himself would "anchor" the team by delivering the initial orientation lectures. He would then arrange for hardware, software, and applications specialists to do lectures and demonstrations in their fields of expertise and to conduct the laboratory sections of the courses. In addition to "anchoring" the courses, he would also interview the customers ahead of time to determine their specific information and training needs so that he, in turn, could pass these along to the specialist before the course took place. He also structured the course and delivered transitional lectures to link one segment to the next. According to the training manager, this initial training-delivery approach worked because it was well-suited to the small, flexible company that specialized in customized design, and also because it was well-suited to the multidisciplinary nature of robotics training -- which involves mechanics, pneumatics, electronics, software programing, and other skills

Current Organization

In addition to the manager, the Training Department now has an instructor who specializes in hardware training and will soon have a software instructor. The following organization chart shows the reporting relationships:



The training manager, as illustrated above, reports to the manager of customer support. However, the training manager and the trainer have free access to employees and managers in other departments. Although the hiring of the full-time hardware instructor has reduced the need for hardware specialists in other departments to assist in the customer training courses, higher level software training is still delivered by technical specialists from other departments, and hardware applications specialists are still called on when needed. The training department still, therefore, relies on the concept of the teaching team comprised of both specialists and generalists; and it still fulfills its original function as broker between the customer and the internal technical specialists.

Training Department Philosophy and Goals

The philosophy of the training department is an extension of the company philosophy. Because of its size, the nature of its product, and the approach of its top management, Automatix is, according to company representatives, "on fairly intimate terms with its customers." In the process of selling, tailoring, and installing the systems in customer plants, Automatix employees become involved in the customer's operations. Support and service after installation entails further involvement. In the words of the training manager, "quite a bit of effort is put into working with the customers to try to build long-term relations with them, and to build trust in this small, high-tech corporation which is located on the east coast — not exactly the manufacturing center of the United States. They look at us (especially the metal benders and cutters from the heavier industries) and think, 'they're small, high-tech-egghead-computer-jocks up there.' After exposure to us, they think, 'they're small-high-tech-egghead-computer-jocks who work hard and will work with us and do everything it takes to get the job done.'" The training department reflects that general philosophy by attempting to remain flexible to meet the various needs of different customers and delivering customized training courses when the need arises.

The major goal of Automatix training is to provide the customer with the skills and information required to make productive use of the systems in order to enhance the overall productivity of the customer's operation. In support of that goal, customers are trained to operate and maintain their systems effectively. In addition, they are taught how to evaluate and implement new robotic applications and how to use the Automatix AI-32 control processor in those applications.

Training Department Staff

The training manager has a master of education degree and a bachelor of arts degree in public communications. His past professional experience includes university administration and teaching, counseling, publications, and some work on video productions. The instructor has an associate degree in engineering and was previously employed as an electronics and hardware technician, and later as a trainer, at a small computer firm. To flesh out the technical expertise of his department, the training manager is currently looking for an additional general purpose instructor. He would also like to hire another technical instructor and a curriculum writer with broad expertise in writing technical curricula. Aside from technical skills, the major requirement for the potential new hires is the energy and flexibility seen as necessary to keep pace with the activities of the high-growth firm.

Facilities and Equipment

The Boston area facility contains one classroom/laboratory and a demonstration area used for hands-on training. At present, the training department shares three visual inspection systems with the applications department, but must borrow robots and control systems from other departments when training is in session. When the need occurs, trainees move into other departments' facilities for demonstrations or, occasionally, for specialized hands-on practice.

Contractual Arrangements with Customers/Training Costs

Customers who do not purchase maintenance contracts receive free training for two employees per system for the first three systems purchased. If four to nine systems are purchased, free training is provided for eight customer employees. Nine employees are trained free of charge when 10 or more systems are purchased. Customers who purchase a "standard maintenance contract" receive the following training credits: 2 employees per system for the first 3 purchased; 9 free training slots when 4 to 9 systems are bought; and 10 employees trained with 10 or more systems. Customers who purchase "critical customer service" contracts receive still more training credits.

Training for additional employees is priced at \$750 per week or, for periods less than a week, \$175 per day. Training onsite at the customer's plant costs \$1,000 for the first day, and \$750 for every day thereafter.

Training Delivery

Aside from the formal training courses described below, the Automatix customer receives what is, in effect, a series of informal training sessions from a variety of sources within the company. Applications engineers work with the customer to design the system and, in the process, provide demonstrations and explanations of how the system will perform.¹⁷ Since the system is normally installed before formal training takes place, the Automatix field service engineer who does the installation provides additional informal operations training. After the formal training has been completed, customers

17. One or two customer-visits to the Automatix factory usually precede system delivery.

who have purchased particularly complex systems will receive more assistance and on-the-job training from an applications engineer. When problems arise, field service representatives often provide additional on-the-job training along with maintenance support.¹⁸

Overview of Training Courses: Standardized and Customized

Formal training courses are offered for each of the three major products: the arc welding robot system (Robovision); the vision system (Autovision); and the robotic assembly and processing system (Cybervision).

Robovision training, offered on the average of once a month, is a standardized training package and usually does not require tailoring to accommodate the customers' individual applications.

The majority of Autovision courses are also standardized. Even though each Autovision application requires a different operation, the systems are operated by a menu-driven program. Therefore, general instruction in how to use the menu and specialized attention during laboratory exercises accommodates a wide range of students learning to operate Autovision for different applications.

Cybervision courses, on the other hand, deal with the maintenance and operation of a large, complex system and are highly customized to accommodate the custom-design of each system. Cybervision classes — offered approximately once every 3 months — are usually attended by the employees of

18. This series of informal training services is similar to that provided by Computervision, GCA, and a number of other programmable equipment vendors.

a single firm, all of whom are trained on the specific system's application. Cybervision courses are team-taught by the training department staff and Automatic application engineers.

At the customer's request, tailored courses are also delivered on the Autovision and Robovision systems. One such customized Robovision course -- delivered to welders from Westinghouse's Defense and Electronics Systems Center in Baltimore, Md., and researchers from Westinghouse's Manufacturing Systems and Technology Center in nearby Columbia, Md.-- is described in detail in case study No. 14 of this series.

Course Length

Robovision and Cybervision training is divided into two segments: operations and maintenance. Each segment is 2-1/2 days long, and the operations and maintenance segments for a particular system are delivered back-to-back. Trainees, therefore, may take either or both segments, although Automatic recommends the operations segment as a prerequisite for the maintenance segment. Since the Autovision systems have fewer mechanical parts than the other two, Autovision maintenance and operation are combined into a 3-day course.

Occupational Categories of Trainees and Prerequisite Skill Requirements

Trainees range from R&D personnel and project engineers to welding foremen and line supervisors to maintenance personnel. For the most part, operators do not attend the courses -- the usual procedure being for the foreman or welding engineer to take the Automatic class and return to the home plant to teach the operators. (The Westinghouse course mentioned above was

unusual in that Automatix trained the shop-floor welders directly.) In the Robovision and Cybervision courses, the customer research specialists and project engineers often take only the 2-1/2 day operations segment of the courses, while the maintenance personnel (electricians, machinists and tool-and-gauge specialists) will take both operations and maintenance. The training department recommends, however, that the engineers and researchers take the first half-day of the maintenance course, which provides them with a maintenance overview. The majority of trainees attending the Autovision courses are project engineers.

A prerequisite skill for all of the courses is an understanding of the home-plant's application of the system. Additional prerequisites for the Robovision course are familiarity with welding and knowledge of industrial manufacturing terms and procedures. Trainees in the Cybervision courses should, likewise, have a familiarity with assembly engineering procedures and terms. Autovision trainees, if they intend to experiment with the vision system, should be familiar with computer programming.

Class Size

Class size ranges from 6 to 14 students. In order to provide adequate hands-on practice opportunities for each trainee, however, Automatix attempts to keep classes to a maximum of eight trainees. When larger classes are unavoidable, the training manager requests additional assistance from Automatix personnel outside the training department to aid in the laboratory sections, and extra equipment is borrowed from other departments. Automatix's training bulletin lists no minimum class size. According to the training manager, classes have been run for two to three students.

Training Methods and Materials

All Automatix training courses are approximately 30 percent lecture, 20 percent demonstration, and 50 percent hands-on training (1-1/2 hours each morning and 2-1/2 hours in the afternoon). Normally, the training manager delivers the opening lecture, which includes an orientation to the course, an overview of the system the students will be training on, and equipment safety. From that point on, the instructor takes over the class, teaching both the operations and the maintenance segments. In most cases, the instructor is aided by a field service representative and one or two applications specialists who come in to teach specific portions of the class or to help with the laboratory practice. In addition, the training manager has made videotapes of a number of Automatix R&D or applications specialists talking about their specific areas of expertise. (One videotape, for example, features an applications specialist discussing and demonstrating diagnostic software.) The videotapes are integrated into the lectures at appropriate points. When training is delivered at the customer's plant, the trainer is aided by a locally-based Automatix field service engineer and -- if the application is especially complex -- by an applications engineer from Automatix headquarters.

The classes themselves are often attended by a mix of project engineers and research specialists (who are most interested in lectures on design and operation principles) and maintenance personnel (who are most interested in the hands-on laboratory training sections). The instructor normally handles this situation by aiming the lectures at an advanced-intermediate level of understanding and then splitting up the two occupational groups in the

laboratory sections — the engineers and researchers working with Automatix applications or R&D specialists, and the shop-floor personnel working with the instructor (who pays special attention to those trainees who do not have the background to fully understand the lectures).

The approach in the maintenance segments is to train the students to maintain, troubleshoot, and repair the systems to the module-level (component-level repair is most often done by Automatix field service personnel). Each section of the maintenance training is broken into subsections, moving progressively from the system level down to the operating modules of both the controller and the robot. (Operating modules of the robot include, for example, the motor, the harmonic drive, and the chain systems that drive the wrist.)

Instructional material includes task-oriented training manuals, exercises, overheads, videotapes, a special computer program developed for training Autovision students.

Evaluation and Followup

Although students are not formally evaluated, the instructors and courses are. Trainees fill out lengthy written evaluations which are reviewed by the training manager, the instructor, and the manager of customer support after each course. Until quite recently, the courses were modified slightly in response to each set of student evaluations. Now, however, the evaluations reflect that the courses are achieving their objectives, and the training department staff believes that little structural modification will be necessary in the future.

No formal followup procedures have been instituted. However, the close contact between Automatix and its customers and the "informal training" provisions discussed above give the training department ample opportunities to keep track of former trainees and post-training problems.

Results

In 1982, approximately 300 customer personnel attended Automatix training courses. Training delivered informally by field service personnel equaled or exceeded the formal training numbers. The training department estimates that approximately 500 trainees will receive formal Automatix customer training in 1983.

IV. PRESENT AND FUTURE TRAINING PERSPECTIVES

The object of this section is not to draw direct comparisons between the three training organizations profiled in sections I to III. Although all of the training departments support computer-aided design or manufacturing equipment sales and service, the quite significant differences in terms of company size and age, number of systems on the market, uses and users of those systems, and other variables make direct comparison neither prudent nor particularly useful.

Computervision produces multipurpose computer-aided design and drafting equipment that can be used for a number of purposes (from mechanical design, to integrated circuit design, to architectural design) by a variety of businesses and industries. Automatix configures customized robot systems and produces vision systems which serve a narrower market than Computervision

products. The GCA systems described in this study are more specialized yet and are used by only one segment of the manufacturing industry -- semiconductor processing firms.

Aside from the differences in the CAD and CAM equipment the three training organizations support, there are notable differences in the training departments themselves: Computervision's training department has a large staff and has been providing training for 9 years; GCA has been delivering formal training for less than 6 years; and Automatix's two-man training staff has been offering training for less than 2 years.

In spite of their differences, however, the three training departments have some similar problems faced by a number of CAD/CAM training organizations. One object of this final section is to point out problems that are common and some that are unique to each organization. All of the training departments profiled have not only the potential for growth, but also the need to expand to accommodate growing numbers of customers. The descriptive portion of this study pointed out the varieties of approaches to programmable equipment training in different situations influenced by equipment and customer needs, company policy, economic circumstances, and individual training methods. In addition to describing the problems, this section discusses each company's approach to meeting current needs and its plans for anticipating future needs -- not, it should be reemphasized, for comparative purposes, but to bring out the variety of possible configurations of training departments based on approach, philosophy, and the stage of development of each organization.

Problems and Solutions

The three training organizations share a number of common problems having to do with the selection and skill level of trainees, the mix of skill levels or occupational categories within a single class, and a variety of anxieties on the part of the trainees that complicate the trainers' jobs and can detract from the learning situation. In addition, all three organizations have the challenge of keeping their courses current with the frequent hardware and software updates.

Other problems are shared by two of the training departments profiled. Both the GCA and Automatix training departments, for example, have to borrow some equipment from production or research departments, which creates scheduling difficulties. While all three training departments find it difficult to locate and hire good instructors, Computervision and GCA have the additional problem of losing instructors whose skills make them very employable elsewhere.

Still other problems seem to be unique to the individual training organizations — "unique," that is, in the sense that they are not shared by the other two companies profiled here, not in the sense that there are no other companies experiencing the same problems. The Automatix training department, for example, has difficulties related to its small size and recent establishment. GCA trainers deal with especially delicate equipment and, furthermore, deal with customers whose precise processes are closely-kept secrets — both of these factors create training-related problems for the instructional staff. Computervision is now at the stage where a lack of trained users is limiting sales and where outside organizations are beginning to deliver "Computervision" training. Both of these circumstances produce problems (and also some benefits) for the Computervision training department.

These and other problems are discussed in more detail below. The problems discussed on the following pages are not organized according to their commonness or uniqueness; they are, rather, arranged by topic area -- such as equipment problems or trainee problems.

Skill Level and Selection of Trainees

While all three training organizations advise their customers that trainees should have specific prerequisite skills and knowledge in order to derive the greatest benefit from the training courses, the selection of students is ultimately the customers' responsibility. While this problem was mentioned by all three training departments, and while unprepared students can create a number of problems for the instructors, the problem itself occurs relatively infrequently. GCA reports that fewer than 5 percent of its trainees arrive unprepared. Individual help is always offered to the problem student, but those students, according to the training manager, often feel intimidated by tutorial situations.

Problems relating to student selection for GCA training occur primarily in the maintenance courses, which require a relatively unusual combination of skills (electronics, precision mechanics, and some knowledge of photolithography). Computervision operators' courses require a less complex set of prerequisites. Consequently, the Computervision training department has fewer problems with unskilled trainees in its basic courses.¹⁹ Managers who do not have the prerequisite skills do enroll in the basic classes, but this does not usually present a problem. The managers are informed in advance

19. A more prevalent problem in Computervision courses is "computer anxiety." This is discussed on p. 63.

that the classes will not be modified to suit their needs. The majority of managers realize that they will not absorb all of the material but attend the classes anyway to learn as much as they can about the system and the type of operations their employees will be performing.

A more pertinent problem in Computervision basic operations classes is that a number of employers fail to designate their most accomplished and productive designers and drafters as the first trainees on the system. Computervision's Boston area training manager states, "If a customer sends a lousy designer, he'll get back a faster lousy designer." The problem here is not that a "lousy" designer can't learn the Computervision system, but that the employer will not get the productivity increase he expects.²⁰ On the other hand, when the best designers are trained first, they can return to their home plant and either help the less-skilled designers who are trained by Computervision in a second wave, or help with in-plant training of second generation trainees.

Computervision experiences most trainee selection problems in the advanced courses. As mentioned in section I, the prerequisites for the advanced courses include both the basic course in the series plus a specified number of hours of in-plant system time. For CADDS 4 courses, for example, the recommendation is 120 hours for designers and 60 hours for detailers. If a student does not have the appropriate amount of operating experience, the advanced class can be a "disaster" for him or her. This problem does not

20. Computervision's training manager also notes, however, that a highly skilled but "lazy" designer often blossoms into a productive worker after training. This, he feels, is because the lazy designer is often the one who dislikes repetitive work. Since the system reduces repetition and "is extremely addictive," the lazy, because unchallenged, employee often becomes a good CAD/CAM operator.

occur often, because the training department always calls the employer when enrollees do not have the required system experience, and most employers take the advice to delay advanced training until the student has had more practice. A less easily controlled problem occurs when customer employees who have not been trained by Computervision sign up for advanced classes. These enrollees have usually been trained in in-house training programs and have the required system experience. In many cases, especially when the customer has established formal, ongoing in-plant training, the trainee is well prepared to take the advanced class. In other cases, the student may not be. The major problem for Computervision in this situation is that, while the training department knows which of its long-time customers provide adequate in-plant training, it cannot always know about the quality of the training in the plants of relatively new customers, nor does it presume to question its customers too deeply on that point. The preparation of students in advanced classes, then, becomes a problem for the individual instructor, who provides additional help during the laboratory sections and after class, but cannot restructure his lecture for the ill-prepared student.

Automatix has experienced relatively few problems with unprepared trainees. Occasionally, however, when Automatix suggests that the customer send someone with a knowledge of computers to an Autovision course, the customer will send a data processing specialist instead of an engineer or technician with a corresponding knowledge of machine control and manufacturing processes.

Class Composition

A problem related to selection and prerequisite skills is the trainers' difficulty in having to teach classes made up of students with varying levels of knowledge and expertise. This is a problem which could not be completely controlled even if all customers followed the vendor firms' advice in regard to course prerequisites, since the skill levels of employees are bound to vary. In the cases of Automatix and Computervision, the problem of "mixed-skill level" classes is compounded by the additional difficulty of having classes attended by trainees of various occupational backgrounds and diverse information needs.

Computervision has attempted to solve the problem of different occupational groupings by structuring its CADDS 4 classes so that designers and detailers receive some training in common and some training specifically geared to their occupational needs. This was done, not only in response to a training problem, but also in response to changes in the software. CADDS 4 departs significantly from CADDS 3 in that it divorces the designer's function from the detailer's function. In CADDS 4, the designer works in the "model mode," while the detailer works in the "draw mode." In the words of Computervision's Boston area training manager:

In CADDS 4, the designer now has complete certainty that the detailer can't destroy his model, which has always been a fear that the designer has had -- that in erasing lines or creating different views he may have taken out something that is vital. In CADDS 4, we make sure that doesn't happen, because once you go into the draw mode the only thing they (the detailers) can do is erase a line and a view which has no effect on the rest of the model. In a model mode, any change I make on any one of my drawings on any view updates all of them. It's basically like the designer being the sculptor, building the 3-D model, and the detailer then taking photographs of that model and placing them on a piece of paper -- from different vantage points. Once those views are transferred to a piece of paper, any markings I make on that paper does not affect the statue. Yet, if I go back and change the statue, all these drawings get updated. The system gives the customer the ability to lock people

into one mode or the other -- or, more important, to lock them out of one mode or the other.

The coupling of the modeling and drawing functions into one in the CADDS 3 software created training as well as design problems. In CADDS 3 training, the designers and the detailers attend the same advanced course -- which, from the designer's point of view, wastes 2 days on unnecessary detailing commands and, from the detailer's point of view, does not provide enough training focused on detailing commands. In the CADDS 4 courses, both the detailers and the designers take the first week of the basic course, which covers basic operations and two-dimensional drawing; and only the designers stay on for the second week of the course, which focuses on three-dimensional modeling. Separate advanced courses are provided for detailers and designers.

Automatix's solution to the problem of different occupational groups in a single course is to aim the lectures at an intermediate level and to split the class according to occupational categories during the laboratory sections. The engineers and researchers who are concerned with software and applications problems attend labs taught by Automatix applications specialists, while the shop floor supervisors and maintenance personnel attend laboratories focusing on hardware and operational problems taught by the regular instructor.

GCA has less difficulty with mixture of background than with mixture of skill levels within classes, especially maintenance classes where the first 2 days are spent on systems operations. Some maintenance trainees are experienced in system operations while others are not. GCA trainers address this problem by having the experienced class members help the others. This provides additional instruction for the inexperienced trainees and gives the experienced students a chance to review systems operations in a constructive way and to feel that their knowledge is not being wasted during the first 2

days. Although this procedure works in most cases, GCA's training manager believes that splitting the classes would be a more appropriate solution. That solution is currently under consideration by GCA management.

Trainee Anxiety

While the student anxieties observed by GCA, Automatix, and Computervision trainers vary in extent and cause, all of the instructors did note the existence of some sort of anxiety syndrome. GCA trainers reported fewer instances of this problem than the trainers from the other two firms. A possible reason for the relative infrequency of anxiety problems at GCA is that GCA trainees are already working in the high technology semiconductor industry and should have a specialized combination of skills to attend the classes.

While few Automatix shop-floor trainees express apprehension about displacement by robots, other anxieties exist among Automatix students. The instructor notes that project engineers often come to class with anxieties stemming from the knowledge that they are the ones responsible for getting the systems up and running once they get back to their home plants. In the trainer's perception, the project engineers are so concerned about the success or failure of their own application that it is difficult to teach the general principles required before individual applications can be addressed. Their anxieties are often resolved when they are introduced to the Automatix engineer responsible for their particular project and when they are given the opportunity to work on the specifics of their system with the engineer. Some Automatix trainees who have no computer background also exhibit apprehension about being able to learn and use RAIL, the programming language that

communicates with Automatix systems. The training department works to persuade them that "there is no time like the present" to begin learning computer applications and to show them that RAIL is a good first language. Also, the menu-driven programs are user-oriented and contain prompts which help the trainees to operate the system with relative ease. Once students have had a chance to operate the menu, their apprehension generally decreases.

Two problems experienced by Computervision trainees -- computer-anxiety and intimidation by the amount of material to be learned -- have been discussed. Additional causes of anxiety stem from trainees' perceptions that their jobs are being radically changed and the resistance to change exhibited by some trainees -- especially those approaching retirement age. Computervision instructors point out, however, that older designers and drafters who have a solid knowledge of company design procedures are often excellent students and, in addition, are often able to provide a great deal of assistance to younger employees who are among the "second generation"²¹ of Computervision trainees.

Keeping Up with Hardware and Software Updates

All of the training department representatives spoke of the difficulty of keeping pace with frequent hardware and software updates or enhancements while, at the same time, delivering courses. This necessity places a strain on the trainers, many of whom deliver older courses while developing, or at least learning, the contents of new ones.

21. Customer employees who are trained on-site at the customer's plant by trainers or employees who have gone through customer training courses.

The Computervision training department is large enough to be able to dedicate half of the work hours of five trainers to curriculum writing, thus taking the strain off the other instructors, who can devote full-time to learning. On the other hand, Computervision offers almost 3 times as many courses as GCA and over 10 times as many as Automatix and delivers those courses more frequently than the other 2. Apart from developing new courses for new software, the Computervision curriculum writers must develop "conversion courses" for old customers who are already trained on techniques for operating the previous software releases. And, of course, the trainers who are not part-time curriculum writers must find time to learn to operate and teach courses based on the new software.

GCA releases quarterly software updates to its customers, which cause minor modifications in the training programs. This is less of a problem for the GCA training department, however, than the hardware enhancements, especially those developed for the DSW Wafer Stepper system. Some of those enhancements -- the programmable focus control, for example -- do not require separate training courses but are, instead, incorporated into already developed courses.²² Other enhancements -- like the Automatic Wafer Aligner and the Automatic Wafer Handler -- must be supported by separate courses which must be developed by the seven-person training staff.

The two-man Automatix training staff must not only keep up with software updates but must also deliver a number of customized courses (approximately 80 percent of the Automatix courses are standardized; 10 percent have "custom

22. Customers who purchase the programmable focus control and other minor hardware enhancements can usually learn to operate and maintain these subsystems by using the service-and-operator's manual.

islands"; and 10 percent are "one of a kind.") One job of the new software training expert, when he or she is hired, will be to keep track of software developments. For now, the training department must rely on R&D personnel to help them keep pace.

Apart from adding large numbers of new training department staff members, which would put a strain on the budgets of the departments, there is no real solution to the difficulties caused by constant updates. It is "part of the territory" of CAD and CAM training.

Finding and Keeping Qualified Instructors and Curriculum Specialists

Finding qualified instructors is a problem for all of the training organizations profiled. Potential instructors with the technical skills required often have other employment opportunities as technicians, designers, drafters or applications engineers. In addition, the three firms must also look for people with the ability to communicate clearly. It is extremely difficult to find applicants with both technical and teaching/training experience. Automatix, being the youngest of the three firms, must also find people with the energy and flexibility to "change directions on a dime" and the willingness to work overtime until the product line and the training requirements begin to stabilize. Computervision's particular hiring difficulty is the "mix" of trainers required to satisfy shifting customer trends in such disparate fields as mechanical design, printed circuit board design, integrated circuit design, and architectural design. Computervision, therefore, often hires applicants skilled in basic design disciplines and puts them through an intensive 3 to 4 month internal training program. GCA's training department requires a specific mix of skills and abilities which is

difficult to find -- especially, according to the training manager, now that the "all-volunteer army" has reduced the availability of military-trained technicians.

The Computervision and GCA training managers also have difficulties in keeping good instructors. A number of Computervision trainers have been hired by customers to be CAD systems managers. Although Computervision will occasionally hire customer employees for training positions, it is never done without first going to the customer. In general, Computervision looks elsewhere than customer firms when hiring new instructors in order to avoid even the appearance of undermining the very people it serves. The GCA training department is, in effect, a training ground for potential field services and technical support group employees. While this system, according to the training manager, does result in a constant search for new trainers, it provides motivation for "the achiever types" -- who, he says, are usually excellent trainers but whose primary interest is finding new problems to solve. The system, therefore, works to the benefit of both the corporation and employee. Nevertheless, it poses a problem for the training department.

Training Equipment

While Computervision appears to have adequate training equipment to accommodate its students, the GCA and Automatix training departments both have occasional difficulties obtaining equipment needed for specific classes. At GCA, the problem generally arises in relation to Pattern Generator training classes. In most cases, the needed equipment can be borrowed from the manufacturing or engineering divisions. When, however, there is a production problem, it is occasionally necessary to modify the training schedule. While

the Automatix training department shares the ownership of Autovision systems with the applications department, it must borrow robots from other departments. Because the entire Automatix Boston area operation is located in one building, it is relatively easy to obtain the robots for the 4 hours a day of laboratory training. Nevertheless, it does require the training department to scramble for equipment and to depend on the good will of the other departments. The training manager hopes, in the future, to obtain dedicated training robots.

Documentation and Written Curricula

Documentation appears to be an ongoing problem for the three firms profiled as well as for other CAD and CAM vendor companies. Continual software updates must be supported by rewritten documentation and, on occasion, rewritten course curricula or entirely new courses. At GCA, documentation was once the responsibility of the training department but is now done by the engineering division. Operations manuals are written in draft by engineers, delivered to the documentation department for rewriting, and then passed to training and technical support for their comments and additions. Maintenance manuals are usually drafted by the instructors and technical support personnel from available engineering and course support material. They are then sent to the documentation department for editing. Curricular materials are written by the training department staff. This involves a great deal of coordination and, further, involves added duties for the trainers. The training manager believes that the problem could be solved by the addition of one or two technical writers to the documentation department staff who would primarily be responsible for coordination and for curriculum writing.

The Computervision educational services department has, in the past, received customer complaints about the system documentation. For example, a number of users felt that the users' manuals were not "user-friendly" enough. The educational services department makes a habit of incorporating constructive customer criticism into documentation rewrites, and the rewritten documentation done in response to requirements in the Navy contract is expected to improve the documentation considerably. GCA, too, has had problems with customer complaints about documentation in the past. In GCA's instance, the complaints derived from the existence of two sets of maintenance manuals — one for the customer and one for the field service representatives. Although the customer documentation was, in fact, more complete than that used by the service representatives (who needed less complete documentation because of their experience), the customers' perception on seeing different manuals in the hands of field service personnel was that the internal documentation must have been better than theirs. GCA has solved this problem by providing identical documentation to field service and to customers.

The Automatix training department currently uses the operations and maintenance manuals written by Automatix development engineers as the basis for the course curricula. Approximately 90 percent of the course material comes straight from the technical documentation for the systems. The reason for this is, quite simply, lack of time on the part of the training staff, who are currently writing training-oriented manuals in what little spare time they have. The addition of a curriculum writer to the training staff should ease this problem considerably.

Problems Unique to GCA

Because of the nature of the equipment it produces and the nature of the semiconductor industry, GCA has a number of training-related problems that are not shared by the other two firms. The DSW Wafer Stepper weighs 1,977 pounds and stands over 6 feet high. Nevertheless, it incorporates the extremely high degree of precision and optical resolution needed to produce highly detailed circuit paths separated by distances measured in millionths of an inch. A major goal of training, therefore, is to instill the sensitivity required for handling precision electromechanical equipment; it often happens that those students who have the necessary skills to maintain the system electronically do not wield a screwdriver with enough precision to do the mechanical troubleshooting -- and vice versa. When this set of skills does not exist in the same person, GCA trainers encourage the trainees to team up with a person who has the skills they are lacking. This must be done both during the training and back at the home plant if maintenance is to be done effectively.

Another problem peculiar to GCA training is the necessity of teaching students to distinguish between process-induced problems and instrument malfunctions. According to the training manager, some trainees do not really understand what it is the DSW system is making and what happens after the DSW prints the circuit patterns on the wafers. While the circuitmaking process is reviewed during the training sessions, many of the trainees have never seen the actual design and building of the circuits themselves. Their sense, therefore, of where they fit into the entire process is often limited. Another problem arising in this area is that it takes a highly experienced technician or engineer to determine the origin of some problems (i.e., process or equipment). After the wafers are imprinted in the DSW, they go through a

photochemical process, the precise nature of which is peculiar to each semiconductor manufacturer. When the final product is flawed, it is often difficult to determine the cause of the error, since identical-looking symptoms can be caused by either exposure or focus errors in the DSW or by errors in the photochemical process. Since the precise photochemical processes used by the trainees' companies are proprietary and, therefore, unknown to the GCA trainers, they have a severely limited capacity to teach students how to separate process problems from instrument problems. The only thing the trainers can do in this instance is to teach the students how to eliminate, or at least locate, equipment malfunctions, so that the probable source of the problem can be narrowed down. All this is further complicated by the fact that the problem can also stem from a flaw in the wafer itself.

The process/equipment problem will be most extreme in a new course developed by the GCA training department. The course supports a new DSW feature called the SxS site-aligner, which performs an automatic through-the-lens alignment for each individual image field on a wafer before it is exposed. The site-by-site (i.e., one alignment per image field) system improves registration tolerances.²³ This, in turn, allows GCA products to be more accurately matched to other DSWs or to the systems produced by other vendors. The use of the site aligner is dependent on a knowledge of both the equipment and the specific photochemical process used by the customer. The GCA training department is, therefore, in the position of delivering a course which is approximately 50 percent process-dependent without knowing what, precisely, the process of each customer is.²⁴ The course, as it is now

23. GCA Profile, No. 14 (1981), p. 17. The site aligner is an option for those manufacturers producing VLSI (very large scale integration) circuits.
(cont.)

structured, covers the process in a general way, but it must be left up to the trainees themselves to convert the general process material covered in the course to their particular process. GCA does, however, provide application support through its engineering staff during and after site-aligner installation. It is anticipated that the site aligner courses will be attended by process engineers and maintenance personnel, and that separate classes will be held for each customer's group of trainees.

Varieties of Approach

Although the statements of training goals provided by each company contain individual variations, they all have a similar underlying objective: to help the customer make the most effective use of the system to insure system productivity which, in turn, should enhance the productivity of the customer's operation. The variety of approaches utilized to reach this common goal can be traced to a number of factors including the philosophy of management, its age and experience, the type of programmable equipment sold, the potential uses of that equipment, and the nature of the industries making up the customer base.

While Computervision training is primarily focused on how to use the systems effectively and creatively, the training provided by Automatix and GCA is focused both on operations and maintenance. Since GCA systems contain a complex array of subsystems, the majority of GCA's training courses focus on system maintenance. Automatix courses, which support systems specifically

designed for individual customer applications, cover operations and maintenance equally. Both GCA and Automatix take a systematic approach to maintenance training, teaching students to work from the systems level down to the module level -- and, in some cases -- to the internal board function level. That the time devoted to hands-on training in all three cases is equal to the time allotted to lecture, discussion, and/or demonstration emphasizes the recognition that practice is a major component of the instruction.

Computervision educational services department representatives maintain that "CADD training demands a specialized instruction program because it is closer to 'education' than to 'training.' It tends to involve creative and intellectual processes rather than manual skills; the latter being more characteristic to typical industrial training programs."²⁵ Computervision's "systems approach" to training (or education, as the case may be) does involve performance objectives, but the major thrust of the basic training course is first, to get the students comfortable with a new mode of thinking and operating so that they can interact with the system, and second, to teach them the concepts required to operate the system. These concepts, learned through intellection and reinforced by practice, then become the bases for learning advanced techniques which increase the user's ability to make the most productive use of the system.

Aside from the different approaches dictated by computer-aided design versus computer-aided manufacturing training are the differences dictated, at least in part, by differences between systems with general hardware

25. This perception, together with Computervision's "systems approach to instruction," should be compared to the approach taken by CADAM Inc (case study No. 6).

configurations used by all or most of the customers and systems (like those Automatix configures) which are custom-tailored for the individual user. Both Computervision and GCA trainers prefer teaching to groups of 3 (in GCA's case), or 4 (in Computervision training), up to a maximum of 8 to 10. While the minimum requirement is partially based on cost-effective training delivery, both GCA and Computervision instructors believe that more than one or two trainees results in a more effective learning environment by forcing the instructor to cover all of the basics, rather than teaching to the needs of one or two students, and by creating an interactive environment where students can learn from each other. Automatix trainers — who teach two courses (Autovision and Cybervision) which are especially oriented to the specific applications of individual customers — have found that, for their purposes, the maxim "the fewer, the better" applies.

Other differences derive from factors previously mentioned, such as individual company philosophy, the longevity and size of the training organization, and the customer makeup. Computervision's educational services department, the oldest of the three training organizations, has 9 years of experience in the customer training field and, furthermore, has more systems installed in a wider variety of customer plants than the other two companies. The educational services department, therefore, has had both the time and the need to build up a large group of trainers skilled in a variety of applications. The hiring requirements for new instructors reflects both the training philosophy and the need to serve a broad customer base. While actual experience in the use of computer-aided design equipment is desirable, the real requirement is design or drafting expertise in a specific mechanical, electrical, or architectural design field or in NC part programming. The precise mix of applications skills in the training department must reflect

customers' needs, but must also be flexible enough to accommodate shifting customer trends. This can only be accommodated in a training department the size of Computervision's. While Computervision has hired some vocational education teachers, the training department philosophy is that "good teachers are not necessarily born, but made" and "communicative ability and the ability to speak the user's language" are more important than formal teaching experience.

The GCA training department, which serves a well-defined narrow segment of the industrial marketplace, requires instructors with a precise mixture of technical background and skills. Although the smaller market for GCA systems requires fewer courses and fewer trainers, a number of the courses are lengthy (2 to 3 weeks) and complex and require high level skills and knowledge on the part of the instructor and the students.

While all three companies are high-growth firms that must move rapidly to take advantage of technological advances that can be passed along to the customer, Automatix -- the youngest of the three firms with the smallest training department -- feels most keenly the necessity to move at a rapid pace, maintain the flexibility to meet specifically-stated customer needs, and to stretch itself to its limits. Automatix chose to build its training department around a manager with a formal background in education and communications who was given the organizational authority to draw on whatever technical resources he needed. The company's small size and its location in a single facility were contributing factors that made such an approach possible. In contrast, GCA built its training department around the technical skills of its instructors, and Computervision built its department around trainers with a broad and deep background in specific design disciplines.

All of the training organizations genuinely solicit and use customer input. Formal GCA customer training was initiated as a direct response to customer requests for maintenance courses on the equipment. The level I maintenance and system evaluation courses were established first, and as customers requested courses that would teach their maintenance personnel to do "deep" (or component-level) maintenance, the level II courses were added. Individual courses are also modified, when necessary, to meet customer needs. Computervision is continually refining its courses and its software to meet customer needs as stated in user's meetings, in course evaluations, and other channels. The CADDS 4 software and training courses were, for example, specifically designed to meet the users' needs. Automatix, too, looks to its customers to provide feedback and constructive criticism to help the training department structure its courses to meet their stated goal of providing trainees with the skills and information required to make productive use of the system and to maintain it effectively.

Present Capacity and Future Plans

Computervision

The Computervision training department, which recently grew from 25 trainers to its present staff of 33 because of the large number of courses required by the Navy contract, is meeting the training requirements imposed by its heavy schedule, but not without strain. The instructors work overtime to accommodate students who want more than the allotted 4-hours-a-day of system time on the training equipment and are constantly working to learn new techniques required to teach new CADDS software courses and new applications. In spite of the 6,500 student/weeks training anticipated for

1983, Computervision representatives say that the limited availability of trained users is one of the limiting factors on the growth of the CAD/CAM industry. "There are," they say, "a number of employers who would like to jump in, but can't afford the 9 months required for users to become fully productive." Computervision's "train the CAD/CAM trainer" course, geared for companies planning on delivering their own Computervision training, has been offered for the past year, but has just recently registered enough enrollees to be delivered. To increase the number of trained users, Computervision operates an active university donation program. Over 20 systems have been donated to colleges and universities throughout the country, together with free training courses for the professors who are responsible for teaching computer-aided design or drafting.²⁶ Other systems have been sold to educational institutions at reduced prices. Computervision training courses are also offered by number of outside professional training organizations.

While the "train the trainer" course, the computer-aided design education delivered in the schools, and the training provided by professional training organizations promise to create more trained users, there are drawbacks as well as benefits to the spread of Computervision training delivered by outside sources. The Computervision educational services department is fully confident that an experienced user-firm will deliver competent CADDS training, yet it cannot have that level of assurance about the quality of the training delivered by some other outside sources. In addition, much of the CADDS training provided by universities is not focused on training CADDS users but on educating graduate and undergraduate students in the general uses of

26. Computervision intends to donate 10 systems per year to educational institutions.

computer-aided design equipment for their specific engineering, design, or drafting discipline. Students in colleges and universities do not necessarily have the opportunity to build up enough system time to become truly proficient users. Computervision, therefore, while it encourages the growth of CADDS training delivered by outside sources, does not recommend that training to its customers, nor does it wish to take responsibility for training that it cannot control. Thus, the real burden of training customer employees to be effective users falls squarely on the shoulders of the Computervision training department.

The educational services department and other Computervision departments are considering a plan that could have a major impact on the problem of the limited number of trained CADDS users. The plan, if it comes to fruition, would result in the creation of a Computervision Training Institute. The short-term goal for the contemplated training institute is to provide CADDS training (which would be essentially the same as that now delivered in the customer training department) to individual designers, drafters, and detailers who are not company-sponsored but who would pay their own way at the institute to enhance their skills. The long range goal is to create a 2-year program aimed at graduates of high school drafting programs which would provide them with both basic drafting skills and computer-aided drafting skills. At that stage, once the 2-year program is created, the Computervision Training Institute would conceivably be in the position to participate in a Government-funded program to retrain displaced workers or to train the unemployed.

GCA

According to the training manager, the GCA training department is now stretching the capacity of its staff to meet current training responsibilities. Although the department is keeping to schedule and maintaining the requested number of courses, the manager believes that the department, as now constituted, will not be able to keep pace with new course development required by new equipment features due to go on the market in the near future. In addition, GCA has entered into new joint ventures with firms in Japan and Europe. The employees of the two foreign firms will need both formal and on-the-job training to learn the complexities of GCA equipment to enable them to support the customers in Europe and Asia. Another near-future need to which the training department would like to respond is formal training for GCA factory workers, who now are trained on the job. The training manager also sees the need to institute executive training seminars to inform GCA and user-company executives of the capabilities, operation requirements, and maintenance needs of the DSW and other GCA equipment. All this requires an enlarged staff and, possibly, more equipment dedicated to training. The training manager is now in the process of looking for new trainers and anticipates that the training department will double in size within the next year.

Automatix

The Automatix training department, according to its training manager, is in an "early stage of development." Both he and the instructor are "stretched" and must work many hours of overtime to keep up with scheduled courses (both customized and standardized), curriculum development, onsite

training at customers' plants, and course modifications. The training manager notes, however, that Automatix' recent incorporation and rapid growth means that all of its employees are stretched. Apart from the need for more staff to aid in all of the training and training-related activities, the training manager also sees the need to build up a staff of technical specialists -- in particular, a software specialist and a curriculum writer. The need for specialists inside the training department will grow yet more intense as the company itself grows and communication and interchange between employees of various departments becomes more difficult. In spite of the increasing need for specialization, however, the training manager hopes to be able to maintain the original Automatix focus on the importance of well-developed communications skills in delivering industrial training courses.

The training manager intends to increase the department's already-active use of videotape to give the students the benefit of lectures and taped demonstrations by Automatix applications and research specialists and hopes to be able to take advantage of computer-aided instruction (CAI) technology in the future. He is now exploring CAI authoring systems, and plans on utilizing the expertise of Automatix programing staff to help develop CAI instructional aids.²⁷

27. Computervision is also looking into computer-aided instruction as a training aid. The Computervision audio-cassette courses, while they do allow for self-paced study, have no interactive capabilities. The Computervision training department would like to develop a videodisk- or videotape-based computer-aided instructional course which would use the Computervision system itself as the medium for instruction. CAI is not, however, expected to replace classroom training.

Closing Summary

Apart from illustrating the variety of possible training approaches -- some dictated by the nature of the equipment and the needs of the users and others chosen to suit the personality of the company and its employees -- Computervision, Automatix, and GCA also have some significant similarities. All see the need for some sort of systematic approach to training -- whether it be the system-level to module-level approach seen in Automatix and GCA maintenance training or the systems approach to instructional technology employed by Computervision. In addition, all three companies recognize the necessity of combining technical skills with communications skills, even though one set of skills may be given more emphasis in different training departments. Automatix's move toward increased specialization and Computervision's and GCA's insistence on communicative ability to match technical knowledge and skills are indicative of different approaches used to reach a common goal: that of helping the student to understand and make effective use of the computer-aided equipment. All of the companies profiled here recognize that if their customers' employees are not well trained, the customers may not experience the productivity gains they expect. While training, therefore, may or may not be uppermost in the minds of the corporate executives in the three vendor firms, all are aware of the vital importance of customer training as part of the service support system for their products.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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- C.7--OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS: ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS
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OFFICE OF TECHNOLOGY ASSESSMENT
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COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.7— Oakland County Vocational Education
Centers: Robotics and Computer-Aided
Drafting for High School Students**

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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS:
ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS

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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

**OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS:
ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS**

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**OAKLAND COUNTY VOCATIONAL EDUCATION CENTERS:
ROBOTICS AND COMPUTER-AIDED DRAFTING FOR HIGH SCHOOL STUDENTS**

BACKGROUND/SUMMARY

The Oakland County Intermediate School District covers approximately 900 square miles to the north and west of Detroit. The intermediate district is comprised of 28 constituent school districts and includes most of Oakland County and small proportions of the adjacent counties of Macomb, Wayne, Livingston, Genesee, Lapeer, and Washtenaw.* The approximately 211,000 children in the district live in communities of widely disparate economic status: some are among the wealthiest in the country while others have disproportionate numbers of families on State and Federal aid.** In 1982, Pontiac, the largest constituent school district, had an unemployment rate of over 20 percent.

In 1967, voters in the intermediate district passed a half mill levy to pay the construction costs for four area vocational education centers, one in each quarter of the county. The four centers--operated under contract to Oakland Schools by the constituent districts of Pontiac, Royal Oak, Walled Lake, and Clarkston--offer programs in 32 occupational areas. Three two-and-a-half hour sessions--morning, early afternoon, and late afternoon--are offered for high school students, who spend the remainder of their school day at the "home" high schools; and the centers all operate evening classes for adults. The flexible vocational instruction offered at the centers complements the vocational education provided at high schools that operate individual vocational programs. The centers also provide basic-through-advanced instruction for students from schools that have no vocational programs of their own. Students who participate in a full 2-year course of study at a

* This is Oakland Schools, a brochure published by the Oakland Intermediate District, explains that "In Michigan, every local school district is a part of an intermediate district; there is no exempt territory. The intermediate school district is a regional educational service agency created by state law to carry out certain legal functions at the direction of the State Department of Education."

** This is Oakland Schools

center get 900 hours of combined classroom and laboratory instruction in a specific vocational area.* Oakland Schools also provides an additional aid to vocational programming in both the local districts and the regional centers: curriculum specialists on the vocational education staff at the Oakland County Service Center assist instructors applying current instructional technology, in keeping program content up to date, in obtaining funds and equipment, and in maintaining contact with local industries (See pp. 11-13 for additional information on the centers).

In the summer of 1982, the Pontiac Center offered a special 4-week introductory robotics program for incoming juniors and seniors. The intensive 64-hour course was a demonstration program designed to test the feasibility of teaching robotics and other "high tech" courses in the centers' regular school-year and summer offerings. As a result of the successful summer program, robotics and computer-aided drafting are now taught in a number of regular courses in three of the area centers. The centers have approached the teaching of integrated manufacturing skill in a variety of ways: 1) teachers at the Pontiac Center have designed a semester-long course in robotics to be offered in January, 1983; 2) the Royal Oak Center has obtained two computer-aided drafting stations for use in mechanical and architectural drafting courses, and instructors there are using home-made robots to teach basic robotics principles in fluid power and electronics courses; and 3) the Walled Lake Center also has a CAD system for use in its drafting program, and instructors are now using the Mini-Mover "teach robot"*** from the Pontiac summer course to teach electronics, welding, industrial design and machine-shop students the fundamentals of robotics as these relate to the students' core disciplines.

* The number of hours in vocational education curricula is mandated by the state and is comparable to that offered in comprehensive high schools.

** Teach-robots are miniature, table-top electric robots useful for teaching programming and robot motions.

I. SUMMER ROBOTICS PROGRAM, NORTH EAST OAKLAND VOCATIONAL EDUCATION CENTER (PONTIAC, MI)

Planning and Development

The summer robotics demonstration program was conceived during an informal conversation between a vocational education curriculum specialist from Oakland Schools Service Center and the principal of the Pontiac Vocational Education Center. Although the amount of time from initial conception (March 1982) to approval by the Oakland Schools' superintendent's committee (June 2, 1982) to program implementation (June 28) was short, the pre-planning which enabled Oakland instructors, curriculum specialists, and administrators to create the program on such short notice had been going on for the past 10 years.

The pre-planning began, not with robotics itself, but with an ad-hoc group of instructors and curriculum specialists meeting on an informal basis to explore the utilization of computer technology in the classroom. Five years ago, the computer group began preparing for robotics and other industrial applications of computer technology by making--and maintaining--industrial contacts, expanding their working knowledge of microcomputers and programmable controllers, and familiarizing themselves with robotics. All this, according to the curriculum specialist who spearheaded the group, was done in anticipation of the time when robotics would be recognized as a suitable subject for high school vocational education. Because of the necessity of waiting for the proper moment when public interest in robotics would be high enough to encourage the Oakland Schools' superintendents' committee to pass on such a program proposal, the pre-planning was necessarily informal. The years of informal planning, however, proved to be productive; when the board's approval was received in the beginning of June, the computer-group members were able to bring together a team of teachers with expertise in electronics, physics, machining, and computer programming who both devised the curriculum and delivered the instruction. The Service Center curriculum specialist and the Pontiac Center principal bought some equipment and contacted industrial representatives who donated or loaned the remainder and--with the help of the instructors--arranged for field trips to local user and producer firms and for guest lectures by application engineers, sociologists and others.

Goals

The program was designed to meet two sets of objectives. The immediate instructional objectives were to familiarize the students with the fundamentals of robotics to help them make future career and educational decisions, and to increase their awareness of and interest in high technology in general. The long-range goals were 1) to develop, implement, and make necessary modifications to the curricular materials with the object of providing them to secondary and post-secondary educational institutions offering robotics instruction, 2) to develop a core of people within the public educational system with knowledge of robotics, and 3) to demonstrate that a public educational organization is capable of initiating robotics programs in a timely fashion.

Administrative and Instructional Staff

The summer program staff consisted of two administrators, five teachers, and three student programming aides. The chief administrator for the program, the principal of the Pontiac Center, was responsible for student enrollment, obtaining the equipment, arranging for the students to receive academic credit, and other administrative requirements; the Oakland Schools Service Center curriculum specialist coordinated all curricular activities. The team of five instructors developed the instructional materials and designed and delivered the coursework; and the student aides (two college students and one high school senior) were on hand to help with programming and writing software for the Apple computers used to interface with the small teach robots used in the course. All of the instructors had a minimum of 2,000 hours of industrial experience,* two were members of the Education Committee of Robotics International of the Society of Manufacturing Engineers, and some had experience teaching and writing curricula for colleges and other post-secondary institutions.

* Required by the state for vocational education teachers.

Facilities and Equipment

Classes were held in a large classroom-laboratory in the Pontiac Center. Equipment used in the program included four desk-top teach roots (two of which were purchased, two of which were borrowed from distributors), six Apple computers, three cathode ray terminals (CRTs), two DEC writers (strike-on terminals) and electrical and electronic test equipment.

Program Costs

Program costs were covered by the Pontiac Center's existing budget and by tuition charges of \$40 per student. Below is a cost break-down for the four week program.

Instructor Salaries:		\$1,749.42
Equipment/Supplies		
Books	\$70.00	
Computer/disks/screen	1,644.00	
TEM Robotic Arm	2,464.95	
Rhino Robot	3,700.00	
		8,078.45
Repair of Equipment		<u>88.25</u>
Total Expenses		9,916.65
Minus Tuition		<u>550.00</u>
TOTAL COST		\$ 9,366.65

Student Selection

Because approval for the program was received at the end of the regular school year (June 2), student selection procedures were highly informal. The program administrators discussed the program with the guidance counselors in all of the high schools served by the Pontiac Center. By the time the board's approval was announced, however, most of the high schools had started their final examination periods or had released their students for the summer. Schools in two large districts, Pontiac and Rochester, responded by announcing the program over their public address systems, requesting all interested sophomores and juniors apply. Fifteen of the 16 applicants were selected, and all but one completed the 4-week course. Interviewers looked for college-bound students with strong math and physics backgrounds and with some experience in electronics and/or computers. Approximately 75 percent of the

applicants had the recommended background knowledge; the remainder of those admitted were chosen because of their high level of interest in the program. Of the 14 students who completed the program, one was female and one was a minority.

Curriculum

Classroom and laboratory instruction was complemented by field trips to Pontiac Motors, ASEA's midwest robot facility, and a local robotics show. Students also heard guest lectures by industrial representatives from Pontiac Motor Division, ASEA, ETON Corporation, the Kasper Machine Company and by two sociologists who talked about the social implications of robotics. The following topic areas were covered in lectures and reinforced by field trips, demonstrations, and laboratory experiments:

History and Classification -- the factors influencing the growth of robotics in industry; manufacturing processes in which robots are utilized; definition and description of robots and their component parts; robot classifications (non-servo, point-to-point servo-controlled, and continuous path servo-controlled); description of commercially available robots; and the potential areas of growth in robotics.

Simple Machine Process and Robot Terminology-- a description of simple machine functions and the relationship between robot design and function terminology and the basic terminology of machine design.

Basics of Electricity and Motor Operation/Control--an introduction to selected fundamentals of electricity and electronics, specifically DC power distribution and simple DC circuits. Students learned to use basic instruments to monitor electrical power and to locate malfunctioning segments.

Micro-Computer Operation and Programming--lectures and demonstrations of computer operation and practical experience in computer programming.

Robotic Drive Systems -- a segment in which students learned how to address the teach robots with standard computer programs and prepared specific programs for robot operation.

Robot Applications--a review of manufacturing operations related to robot applications and field trips to design and manufacturing facilities.

Opportunities in Robotics -- an examination of the employment opportunities in the field of robotics; requirements of various job classifications as they relate to the individual's development of skills and academic knowledge.

Had the superintendent's committee approval been received earlier, the instructors would have attempted to add another 2-week segment covering pneumatics and hydraulics. Lack of time and difficulty in obtaining equipment, however, made this impossible.

Instructional Methods and Materials

The choice of a team-teaching approach was dictated by the interdisciplinary nature of robotics itself and also by necessity--no one teacher in the Oakland system had all of the background knowledge and skills required to teach the full 4-week program. However, the team of instructors worked well together, and each individual member of the team enhanced his own knowledge of related fields while imparting his particular expertise to the students. The lead instructor--who was on hand at all times to teach specific class segments, guide the students through experiments, and to provide continuity as the course moved from segment to segment--was an electricity instructor employed full-time at the Pontiac Center. Industrial representatives taught the basics of robotics; a physics instructor taught the unit on simple machine processes and aided the students as they conducted physics experiments; an electronics instructor from the Walled Lake Center taught the segments on electricity and electronics; and a programming instructor from another intermediary district taught the basics of programming.

The first 2 days of the program consisted of introductory lectures, films, demonstrations, and a field trip to Pontiac Motors, where the students saw industrial robots in operation and visited the robotics training laboratory. From the third day through the end of the course, the majority of class-time was spent in practical laboratory work, progressing from experiments in basic

physics and electricity through robot programming. Because of the limited amount of time available for each segment and the students' impatience with lengthy explanations of a theoretical nature, the instructors had to condense all of the material and to be highly selective in the presentation of some of the topics. The necessity to condense and select was most challenging in the 3-day electricity/electronics segment which, after an introductory lecture in basic electricity and the importance of electronics to the study of robotics, concentrated on DC power distribution and simple DC circuits. As in the other segments of the course, the object in the electricity segment was to familiarize the students with some of the basic concepts and--most importantly--to whet their interest and encourage them to pursue studies providing them with more complete knowledge of the disciplines making up robotics.

The instructors also worked as a team to develop the curriculum and written materials for the course. Since no texts, manuals, or experiments appropriate to secondary level teaching were available, the instructors--aided by the curriculum specialist and by experts from industry--developed laboratory manuals, experiments, a robotics glossary, and hand-outs defining and describing robot functions, components, and classifications. In addition, the instructors also developed computer software for use by the students in programming experiments.

Student Evaluations of the Program

In written evaluations, most students noted that they had enjoyed the class. The majority were impressed by the team-teaching approach and the opportunities for individualized instruction. A number stated that they intended to pursue robotics studies and some claimed that the course helped them to decide upon a future career in robotics. Some students noted the lack of training in hydraulics and suggested that it should be included were the course to be repeated. The other criticism received was from two students who felt that the electricity segment was too theoretical. The instructors are now considering methods of dealing with the electronics segment in future familiarization courses. Suggestions include 1) placing the segment later in the course when students would be better able to understand its relevance; 2) making provisions for a supplemental class for those with no background in

basic electricity; and 3) teaching electronics as it applies to robotics, rather than beginning with pure electricity/electronics.

Course Credit

All of those who completed the course received a half unit of credit, which was entered on their high school transcripts (one credit equals a full semester-long course).

Relationships with Industry

In the spring of 1982, program administrators and members of the instructional team met with General Motors representatives from the Orion Plant (a new facility with over 160 robots, which, at the time, was under construction) and from Pontiac Motor Division to determine the feasibility and appropriateness of offering robotics on the secondary level. The GM representatives and other industrial contacts agreed that introductory courses in robotics on the secondary level would not only benefit the students by providing them with an orientation to the field, but would also benefit industry by raising public awareness and student interest. These industrial contacts, made in the pre-proposal stage of the program, also proved to be fruitful in the curriculum planning and program operation stages. The Pontiac Motors representative not only worked with the instructors to develop the curriculum, but also delivered the introductory lecture to the first class and arranged for a field trip to the Pontiac plant. Other industrial representatives from firms that produce, distribute, and use automated machinery donated time and equipment to the program. While no formal industrial advisory committee was established before the summer program was offered, the curriculum specialist who helped administer the program (who is also the vocational/technical coordinator for the Oakland district) has set up an informal committee to provide advice on present and future programs and coursework (see pp. 21-22).

Relationships with Labor Unions

Local labor unions were not involved in the summer program, primarily because school officials looked on the summer course as a test case which would help them to develop prototype curricular materials which, they felt, were needed before asking for union advice or participation. Before the downturn in the

area economy, local labor and company officials actively recruited students from the vocational education centers in the district, so that school representatives believe that union participation in an advisory capacity would be appropriate for computer-aided manufacturing coursework. Vocational education representatives are now making informal contacts with union shopworkers and hope to increase the level of contact with local unions in the near future.

Results

Apart from achieving its objective of providing the participating students with an orientation to robotics, the summer program had a number of salutary results. As one of the country's first robotics programs on the secondary level, it generated a great deal of public interest and received coverage in local newspapers, on local television stations, and in publications like the Manpower and Vocational Education Weekly and publications of the American Vocational Association. This positive publicity not only helped to convince school board officials of the viability of high school programs in robotics and other high technology areas, but also generated the beginnings of a communications network between Oakland Schools and other high schools both in- and out-of-state. The vocational education curriculum specialist who coordinated the program has received over 60 letters and calls from high schools, colleges, universities, and industries from across the country, all of which are either interested in establishing programs or have already done so. The local publicity also increased student interest in other programs offered by the centers. The Pontiac Center, for example, attributes an increase in enrollment for its electricity course to interest engendered by the robotics program. Enrollment increased from 35 in fall 1981 to 50 (capacity enrollment for two sections) in fall 1982.

Another result of the program can be seen in the current offering of three of the Oakland vocational education centers (discussed in Section II) and in a number of local high schools in the constituent districts served by the centers. The equipment purchased for the summer program is now in use in two of the centers. Most of the instructors who participated in the program brought robotics into their regular school-year classes (either as a segment in existing courses or as a free-standing, semester-long course) in the

centers or in local high schools; and other instructors in the centers are now offering or planning to offer coursework in robotics or computer-aided design. The summer program also helped Oakland School officials to set up an articulation process with local private schools, community colleges, universities, and three industrial robotics programs. The district is setting up a formal articulation agreement with nearby Oakland Community College whereby students who take robotics coursework in the Oakland Schools will receive advanced standing in the college's robotics program. The articulation process with the other schools and programs are, to date, informal. Other tangible results include the curricular and instructional material developed by the summer instructors--manuals, instructional units (both lectures and experiments), computer software designed for student use, the robotics glossary, and a study analyzing the reading level required for currently available robotics texts. These materials, and the experience gained in developing them, are now being put to use in classroom and laboratories throughout the district and will be refined and expanded in the immediate future.

II. ROBOTICS AND COMPUTER-AIDED DESIGN INSTRUCTION: 1982-1983 ACADEMIC YEAR

Vocational Education Centers

The four centers in the Oakland Schools intermediate district have a total high school student enrollment of 4,199. Because the programs in the centers serve students with a wide range of needs and capabilities--from "special needs" students to college-bound youngsters--and because some students enter the center programs with vocational skills developed in "home" high school courses while others must start from the basics, the instruction provided in the centers is both flexible and individualized. Instructors spend a large proportion of their in-class time guiding students through projects geared to their individual skills and knowledge while, at the same time, providing a coherent 2-year (900-hour) course of study in specific vocational areas.

While the centers provide students with the opportunity to complete a full 900-hour program in a specific occupational field, they also give students the freedom to explore other areas if they discover that their first choice of programs does not suit them. This freedom to switch area of concentration is

hampered only by the availability of space in individual programs. The centers, in fact, have become so attractive that most have waiting lists and have had to establish quotas for each participating high school and for each vocational program.*

Every 5 years, the vocational education staff in the school district surveys county employers to ascertain current and anticipated labor needs and the degree of skill required for entry-level jobs. Other surveys assess the vocational interests of both students and their parents. All of the survey data is then used as the basis for curriculum planning and development in the centers and local high schools. Local industrial advisory committees established for each occupational program also help to keep the instruction in line with current industrial needs by reviewing course content and recommending necessary modifications.

The following statistics provided by the Walled Lake Center in the southeast section of the district are indicative of the results of the vocational education in all four centers: Approximately half of the graduates of the Walled Lake Center have continued their education at community colleges or 4-year post secondary educational institutions; 33 percent of the graduates obtained immediate employment in the field in which they were trained or an allied field; 27 percent were placed in unrelated fields; and 38 percent combined advanced schooling with part-time employment, bringing the placement rate for both full- and part-time employment to 98 percent. The job placement offices in each of the centers contact over 300 employers each year, and a number of employers send notification of job openings to individual instructors, who then arrange interviews for their graduating students. Instructors also aid the placement office by following-up with students after they have been employed.

Aside from the regular school-year programs, the centers also offer summer

* Screening and selection of students is the responsibility of the local high schools.

courses which attract a number of college-preparatory students who do not attend during the academic year because of scheduling difficulties.* The centers are also open in the evenings to serve adults requiring skills training or upgrading.** These evening courses are operated by the district's adult education department.

Curriculum Overview

A total of 10 instructors at three of the vocational education centers are integrating robotics or computer-aided drafting into their regular occupational programs. This section presents a brief overview of the various approaches taken by the instructors at each center.

At the Pontiac Center, the lead instructor from the summer robotics program is developing a semester-long robotics course to be offered in the Spring semester of 1983. The course is designed to provide 51 students who have taken at least 240 hours of coursework in basic electricity, electronics, and motor controls with an overview of computer-aided manufacturing (with an emphasis on robotics) to aid them in making future educational and occupational choices. The course will cover the history of computer-aided manufacturing and design, computer familiarization, computer programming, robot familiarization, and robot operation. It will include laboratory experiments with two small teach robots (a Rhino XR-1 and a Teach Mover) which can be programmed by the center's Apple computers. The instructor also plans to interface the center's Heath Kit microprocessor training system with both of the robots and with motor control equipment for additional hands-on exercises.

Whereas the Pontiac Center plans to offer a full-semester course in robotics as part of its electronics program, instructors at the Royal Oak and Walled Lake Centers are taking an interdisciplinary approach. At the Royal Oak Center, both the fluid power and electronics students have constructed simple

* A number of college-bound students do, however, attend during the school year by taking a full academic course load from 7:00 a.m. to 2 p.m. and attending center programs from 2:15 to 4:45.

** At the Walled Lake Center, some adults are enrolled in the daytime drafting course (which has a CAD and a robotics segment). The Walled Lake Center also plans to offer computer-aided drafting in the spring semester's adult program.

robots with the aid of welding and machine-shop students and instructors, and the electronics and machining instructors are now "trading" classes for 2-week periods to give the students a basic introduction to related disciplines. Teachers and administrators at the Royal Oak Center are also discussing the possibility of forming a "program cluster," which will provide a larger amount of interdisciplinary experience for electronics, mechanical, and fluid power students. In addition to robotics instruction, the center is also providing drafting students with the opportunity to familiarize themselves with computer-aided drafting techniques. The architectural and industrial drafting classrooms share a Tektronix Computer-Aided Design (CAD) terminal, and students in these programs take turns working at the terminal to learn basic drawing, programming, and operation techniques.

The Walled Lake Center also has a Tektronix terminal, used in its engineering design and illustration program. Students in this program learn the history of computer-aided design and drafting, basic programming, digitizing, and equipment operation. These students also share the use of the center's Teach Mover robot with students in the electronics, machining, and welding programs, all of whom receive an orientation to robotics as it relates to their specific disciplines. The electronics instructor, who taught the electronics segment in the summer robotics program, is devoting 10 to 15 percent of the academic-year electronics course to robotics. Students in this course--who have already covered motors, solid-state control, and microprocessor applications--study the history of robotics, human factors and social implications, the manufacturing process, mechanics and simple machines, basic electricity, programmable controllers and computers, robot drive systems, the robot trainer, and career opportunities. Machine shop students learn to program and position the robot for pick-and-place operations, and welding students are attempting to simulate welding robot operations by attaching the teach robot to a turntable and placing a felt pen in its gripper. While the Walled Lake Center has less formal plans than Royal Oak for clustering CAM*-related programs, instructors and administrators report that students in the various occupational programs using the teach robot have already begun to meet on their own time to share information and ideas about the application of robotics to their various fields.

* Computer-aided manufacturing.

Effect of CAD- and CAM-Related Instruction on Instructional Methodology

A number of instructors at the various centers stated that the introduction of computer-aided manufacturing and drafting into their programs is quite likely to change the traditional method of secondary level vocational instruction, especially in the disciplines comprising the field of robotics. The traditional method of instruction, whereby students in vocational programs attend a sequence of courses taught by one instructor or a set of instructors who are experts in a specific field (electronics, for example, or machining or pneumatics), may be modified to enable students to receive periods of related instruction by instructors who are experts in complementary fields. Because of the interdisciplinary nature of robotics and other aspects of computer-aided manufacturing, no single instructor (at least at this point in time at the Oakland centers) has the expertise to incorporate all of the required sub-fields of knowledge and applications.

Another modification--or, more precisely, an addition to the traditional vocational education instruction--may be occasioned by the relative inexperience of many instructors with computer programming. A number of the instructors are themselves in need of such instruction, and others who are familiar with programming are in need of assistance in learning methods for teaching programming to their students. One possible solution to this problem now under consideration by Oakland Schools vocational educational specialists is the addition of a traveling programming specialist, akin to the reading specialist who travels from school to school to teach special reading classes. The district has already formed firm plans to offer intensive programming courses for instructors in 1983. These courses will focus on programming specifically related to the instructor's vocational areas, and it is hoped that those instructors who take the course will become "in-house programming experts" at their respective centers or schools and will aid other teachers in need of programming instruction.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY

Aided by the vocational/technical staff at the Oakland Schools County Service Center, the four vocational education centers in the Oakland district have the capacity to offer occupational training programs that respond to local industrial needs, and, therefore, to the needs of students seeking employment in those industries. Furthermore, the centers are able to implement innovative programs that are beyond the capacity of individual secondary schools, which must balance the needs of general and academic education with vocational education. The centers operate on budgets ranging from \$1 million to \$3 million per academic year and each center maintains close contact with local industrial advisory committees.* The resources available through budgeted funds and through donations of parts and equipment from advisory committee members and other industrial contacts provide the centers with well-equipped laboratories; and the close coordination between the centers enables them to share special equipment items such as the teach robots now in use in a number of the centers.

Evaluation of the centers' present capacity to provide robotics and computer-aided design instruction to secondary-level students is complicated by a number of factors. First, the courses (or, in some instances, the course segments) are in various states of development and/or implementation. At this writing, only one of the academic year offerings had been completed and some had not yet begun. Second, the instructors at the various centers are approaching the coursework in a variety of ways: goals, content, structure, and length vary widely from course to course. Furthermore, the instruction in computer-aided design did not have the benefit of the years of informal instructor development and pre-planning devoted to the robotics curricula. Oakland Service Center and Vocational Education Center representatives freely admit that the preparation in this area is two or more years behind that for the robotics instruction. These two areas of instruction, therefore, although they are both part of Oakland Schools' recent emphasis on "high technology vocational education," cannot be evaluated on equal terms.

* The funds allotted to all four centers for 1982 totals \$6 million (91 percent provided by local funds, 8 percent from State funds, and 1 percent from Federal sources).

While the above mentioned factors preclude a thorough evaluation of the quality of the coursework and the success of the training, the centers' present activities and future plans do provide strong indications of their ability and readiness to respond to the present and future needs of students who plan to seek immediate employment in integrated manufacturing or to continue their education in related fields.

1982 Summer Program

The summer robotics program at the Pontiac Center demonstrated that the secondary vocational education system in Oakland County is capable of responding to technological developments in industry in a timely fashion. As a summer offering the program did not require State approval and could therefore be implemented in a matter of months; and because unofficial preparation had been going on for years, the instructors were ready to complete the work of curriculum design in 3 weeks of intensive effort. Although it was not free of problems and complications, the summer course was successful in terms of meeting its own stated objectives. The students gained fundamental knowledge of robotics and basic programming skills which provided them with an orientation to the field. Furthermore, a number of full-time participants stated that they intend to take additional robotics and other computer-aided manufacturing coursework and plan to pursue careers in robotics or related fields. The program also met its long-range goals of developing curricular materials which were afterwards made available to other centers and high schools and of developing a knowledgeable group of instructors and vocational education specialists. The summer program's success and the positive publicity it gathered increased public awareness of the centers' ability to offer vocational programs dealing with computer applications in industry. The summer program attracted a large number of students, many of them college-bound, to the center's industrial and technical programs; and it gained the active support of school board officials for the implementation of computer-aided manufacturing and design coursework in the centers' regularly offered programs.

Academic Year and Summer 1983 Coursework for Students and Teachers

The basis for both the robotics and computer-aided drafting coursework now offered at the centers was laid by the activities of the "computer group" and the group's emphasis on integrating computer methodology and applications into a number of academic and vocational areas of study. However, robotics--which has more public visibility in Detroit than does computer-aided design--became the major area of concentration for those members of the computer group who were working to integrate the new technologies into their vocational education programs.

Because of the concentration on robotics, the instructors now offering computer-aided drafting as part of their architectural or industrial drafting programs have received fewer benefits from the pre-planning efforts than instructors now teaching robotics, and are experiencing greater difficulties. Because the drafting teachers did not receive their drafting terminals until shortly before the beginning of the fall semester (and, indeed, did not know until the last minute whether or not they would have the equipment), there was little time for the teachers to familiarize themselves with the equipment and its capabilities. None of the instructors had previous formal training in computer-aided drafting and, because the equipment was obtained at a special school rate, did not have the option of receiving the vendor training which is often given to industrial purchasers of CAD equipment. By the middle of the fall semester, the district was able to arrange for 12 hours of in-service training in the operation of the Tektronix drafting terminals used in the courses offering CAD segments, but no such training was available in the beginning of the semester, making it necessary for the instructors to teach themselves how to operate the equipment. While some of the instructors were able to integrate computer-aided design work into their courses from the beginning of the semester, others experienced equipment difficulties and were therefore not able to make use of the equipment for instructional purposes until the semester was half over.

The instructors teaching robotics segments and courses experienced fewer difficulties than the drafting instructors. A number of the instructors who integrated robotics into their electronics, welding, machining, and fluid power courses made use of the instructional materials developed in the summer program. Others, who had included aspects of robotics in previous semesters'

courses using student-constructed robots, films, and/or field trips, have expanded the time allotted to robotics and have found it easier to obtain school board approval for equipment requests.

The center instructors are free to integrate robotics into their programs in the manner they deem most suitable to their particular course of study and group of students. Although this freedom is limited by the number of teach robots and amount of ancillary equipment, the variety of approaches generated by this policy will eventually provide the centers' administrators and Oakland County curriculum specialists with a broad spectrum of methodologies and experience which will help in future planning.

To help other instructors interested in instituting robotics programs, the 1982 summer school team organized and conducted 80 hours of robotic inservice for Michigan's secondary and postsecondary teachers and administrators. These workshops included sessions in industry robotic application labs, in the manufacturing plants where robots are working two shifts a day, in private electronic and robotic training programs, and in the secondary and postsecondary classrooms and laboratories where robotics is being taught on a day-to-day basis. These workshops were conducted in cooperation with the Michigan State University and the Michigan Trade and Technical Educators Association.

In an effort to provide an organized sequence of activities to prepare teachers from various disciplines to apply computers to their specific instructional area, Oakland Schools also joined with Eastern Michigan University to plan and conduct three academic quarters of "Computer Applications in Vocational Education". The courses took place during the 1982-3 school year and were conducted by a professor from Eastern Michigan University and by Oakland Schools' curriculum specialists. The classes met at the Oakland Schools' building where the enrollees had access to an IBM main frame computer and 11 types of microcomputers. Fifty-eight classroom teachers, vocational administrators, teacher aides, special education personnel and others from junior high and secondary schools enrolled in the courses.

The relative success of the initial summer school approach also provided the impetus for area vocational centers to initiate programs during the summer of 1983. The Walled Lake Center is conducting programs in "Computer

Electronics," "Introduction to Robotics" and "CAD/CAM Basic". The Pontiac Center is conducting revised version of "Introduction to Robotics," and the Clarkston Center is delivering an "Introduction to High Technology" program that is a cooperative effort between the electronics department and the modern office practices department.

Present Problems/Future Needs

Although other secondary level programs are currently being developed and implemented, the American Vocational Association and other informed sources agree that Oakland County vocational education administrators and instructors are among a relatively small group of innovators offering computer-aided manufacturing and drafting on the secondary level. The Oakland County teachers and administrators have therefore been faced with problems inherent to the activity of exploring new territory. Most of these problems have been enumerated in the body of this report: no curricular materials appropriate to the secondary level existed; many of the instructors lacked expertise in the computer-aided equipment and had to train themselves; and the limited amount of equipment funds available necessitated the sharing of equipment.

The problem of funds and equipment is an ongoing one and is common to school districts across the country. While the centers could afford to purchase a limited number of teach robots and computer-aided design stations, their equipment allocations do not provide enough funding to purchase a teach robot for each appropriate program or enough CAD stations to allow students more than 10-20 hours each of machine-time per semester. For some of the robotic segments or courses--specifically those taught in electronics programs where the students had some background knowledge which enabled them to study robotics in some depth--more than one teach robot would be appropriate. One possible solution under discussion by the center administrators is the consolidation of all available computer-aided equipment in one of the centers, which would develop a special 300-hour intensified high technology program for high school seniors. If the effort to consolidate equipment comes to fruition, school representatives believe they may be able to obtain an industrial robot for use in maintenance courses. The major drawback to this suggestion is the difficulty of arranging for transportation and the scheduling problems it would cause for those students who would have to travel great distances.

Both the vocational instructors and the administrators are aware of the need for teachers to receive adequate training in computer applications, industrial and otherwise. They also recognize that because of rapid technological developments, this training must be ongoing. Although the instructors now teaching robotics and computer-aided drafting have made a great deal of progress by reading on their own, by working with industrial experts, and by using equipment manuals to teach themselves, a structured program of teacher-training is needed. Local college programs are, of course, available for those teachers who make an individual effort, and the district offers summer school programs in microcomputer applications for all area teachers. The districts have already provided some aid in this areas by providing tuition assistance for 16 instructors who took a course in computer applications from Eastern Michigan University in Ypsilanti (approximately 35 miles from Detroit) but taught in the Oakland Schools Service Center. Sixteen additional instructors will attend this course in the spring of 1983. District officials believe, however, that State or Federal assistance is needed to enable them to undertake such teacher training on an appropriate scale.

Another problem which is related to the need for teacher training is the loss of some vocational education instructors to the industry. Although veteran teachers are relatively well-paid--vocational education teachers with master's degrees and 10 or more years experience make approximately \$31,000 per year, and those who teach the extra third session can make as much as half of that again--some of the district's vocational instructors have accepted higher-paying jobs in industry.* This is a problem for which there is no immediate solution: teachers who have the industrial experience required of vocational instructors in the district and the training experience gained through years of teaching are attractive to industry, and the schools cannot hope to match industrial salaries. Even under the best circumstances, they must rely on dedication to teaching to keep the teachers in the schools.

The problem of the lack of curricular materials is more amenable to a solution. The teachers and curriculum specialists who designed the summer robotics program made a great deal of headway in developing appropriate instructional materials, and this development work is proceeding as more

* Entering teachers with BA degrees and no experience start at \$15,000.

instructors deliver courses and refine and expand the material already designed.

While Oakland Schools representatives have been quite successful in keeping open lines of communication between instructors and administrators within the district, district spokesmen have expressed the need for increased communication with vocational education representatives in other areas. Publications such as Manpower and Vocational Education Weekly and School Shop are helpful in this vein, and opportunities to exchange information do occur in meetings held by national vocational associations. Few school districts, however, can afford to send more than one or two representatives to these meetings, so that most vocational education teachers have little opportunity to learn about new developments in other areas at first hand. Oakland representatives believe that a national clearinghouse devoted to computer applications in vocational education would be of great assistance in solving the communication problem and would encourage the implementation of high technology programs on a nationwide basis. Such a clearinghouse--containing instructional materials, information about local programs, and national and international developments in the field and offering "hot-line" services to vocational education teachers--would not only serve to close the communication gap, but might also help the schools to close the gap between what is taught in their occupational programs and what is practiced in industry.

Another problem was the difficulty in forming a robotics advisory committee in an area in which most of the qualified and interested professionals sit on the advisory committees of local colleges who have formed or are forming robotics programs. High school representatives are hesitant to ask industrial experts, many of whom are already serving colleges in an advisory capacity, to commit their time to yet another committee. Oakland Schools has solved this difficulty by gathering a group of industry representatives who serve as "reference points"--that is, they are on call to answer questions and provide advice, but are not asked to meet formally. Representatives from Bendix, Pontiac Motors, Cincinnati Milacron, Ford, and General Electric serve the school district in this manner.

One of the most significant difficulties facing vocational educators on the secondary level is the public perception of high school occupational instruction and the ongoing public debate on the "proper" role of the high

schools in preparing youngsters for technical and vocational careers. While the vocational education centers in Oakland County are attracting more and more college-bound students, the majority of the students who complete occupational programs move directly into the workplace (either full time or a combination of part-time work, part-time schooling). Instructors who must serve both groups (which are most often mixed in the same class) emphasize basic skills for entry-level employment but, at the same time, encourage their students to continue their education once they graduate from high school. This emphasis on continuing education is especially significant for students interested in computer-aided manufacturing and design where highly developed technical skills and knowledge are required for most but the lowest of entry-level jobs. High schools in the Detroit area have a particular set of difficulties in this regard because of the growing number of post-secondary level CAD and CAM programs in colleges and private vocational institutions and agencies. Some colleges and training agency representatives perceive high school graduates with some training in robotics as competitors to their own more highly trained students and express fears that industries will hire the less trained graduates in lower paying positions at the expense of their own graduates. Other concerns expressed by Detroit area higher education representatives is that, within the next 2 or 3 years, the area will become glutted with aspiring robotics technicians with varying degrees of skill, many of whom may not be able to obtain jobs in the field.

The high school representatives' response to such concerns is that 1) their graduates will not compete with 2-year college graduates and that positions will exist to accommodate both; 2) far from competing with the colleges, they actively encourage their students to continue their schooling; 3) a significant number of their students have the intellectual capacity to go on to college but cannot afford to do so, and these students would "fall through the cracks of the educational system" if they were not given the opportunity to become at least familiar with high technology fields like robotics and computer-aided drafting.

All of these problems have an impact on the present and future capacity of Oakland Schools to meet the need for vocational education in computer-aided manufacturing and design. The fact that neither the local employment needs in these fields nor the role of secondary-level education in filling those needs

is well defined complicates the situation and introduces an element of risk for the educators who undertake the expense and difficulty of developing the coursework and implementing the programs. While the teachers and administrators at Oakland Schools have not found solutions to all of the problems inherent in developing such an effort, they have made significant headway and appear to have the ability to seek out creative solutions, the flexibility to try out a number of approaches, and the willingness to anticipate future needs and prepare for them.

It is possible that more could have been achieved in specific areas of instruction if the district had chosen to devote all of its resources to robotics, for example, or to computer-aided drafting rather than spreading those resources thinly over both areas. Oakland County's approach enables it to fulfill one goal of secondary-level vocational education, that of familiarizing students with new occupational fields and techniques. It remains to be seen whether the second goal, entry-level job preparation, is well served by Oakland's approach. If, however, the district is able to obtain the proper equipment through donations or grants, or if it goes ahead with its tentative plans to consolidate much of its computer-aided equipment and offer a special senior program in one of its centers, its capacity to train for entry-level skills will be enhanced.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

VOLUME II - WORKING PAPERS

Part C - Individual Education and Training Case Studies

- C.1--CINCINNATI MILACRON INDUSTRIES, INC.
- C.2--GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI: "NEW TECHNOLOGY TRAINING"
- C.3--BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS
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Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

C.8— University of Michigan

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:
UNIVERSITY OF MICHIGAN

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

UNIVERSITY OF MICHIGAN

I. BACKGROUND/SUMMARY

Founded in 1817, the University of Michigan is one of the oldest state universities in America. It now consists of three campuses, the largest of which, the Ann Arbor campus, has a total enrollment of approximately 35,000 students and an instructional staff of 2,769. While its primary goal is to provide education to state residents, 30 percent of its incoming freshmen are from out-of-state.

This report focuses on the education and research activities of the Ann Arbor Campus, located approximately 43 miles from Detroit. The majority of the university's projects and teaching activities in integrated manufacturing* are supported by the College of Engineering, which has a teaching staff of approximately 300, an undergraduate enrollment of over 4,200 and a graduate population of approximately 1,300. Other colleges and institutes at the university also provide educational and research opportunities for students interested in pursuing aspects of integrated manufacturing.

In order to encompass the breadth and variety of teaching and research related to computer-aided manufacturing at the University of Michigan, this study will summarize some of the most significant of those activities without attempting in-depth descriptions. The study focuses primarily on the University's College of Engineering, which is pursuing a number of approaches to teaching and research in the integrated manufacturing field. These approaches include 1) the establishment of a Center for Robotics and Integrated Manufacturing (CRIM), which coordinates research and teaching activities in integrated design and manufacturing, robotics systems, and management systems and which sponsors industrial affiliates programs, 2) expansion of computer-aided design (CAD) and computer-aided manufacturing (CAM) laboratory facilities, 3) short summer courses for continuing engineering education, including courses in robotics and the finite element method in mechanical design, and 4) a closed-circuit instructional television network that broadcasts regular college

* "Integrated manufacturing," rather than "CAD/CAM" (Computer-Aided Design and Computer-Aided Manufacturing) is the term preferred by University of Michigan representatives because it reflects the broad range of traditional engineering disciplines and industrial processes that must be integrated in the computer-aided manufacturing environment.

courses to participating industrial facilities in the greater Detroit area. In the area of undergraduate education, the College administration is encouraging faculty members to develop and employ techniques to give students practice working on open-ended problems similar to those encountered in industrial and other engineering environments. While not specifically focused on integrated manufacturing, this activity benefits those students choosing to enter manufacturing disciplines; it develops, in work-related practice situations, the self-reliance and creativity required of manufacturing engineers and others who must deal with constantly changing technological environments. These and other approaches will be discussed in section II below.

This study will also summarize some of the activities of other University of Michigan departments, degree programs, and institutes that offer teaching and research opportunities related to integrated manufacturing. Some of these are conducted by engineering faculty in conjunction with members of other university faculties. The interdisciplinary Ph.D. program in Urban Technological and Environmental Planning, for example, offers an area of concentration in sociotechnological systems, which emphasizes planning for technology in a societal context and includes course work in civil engineering, electrical and computer engineering, humanities, and industrial and operations engineering. The Center for Japanese Studies is coordinating a two-year research project comparing the automobile industries in Japan and the United States in which engineers and social scientists from both countries participate. Other research and teaching activities approach integrated manufacturing from the perspective of nonengineering disciplines. Faculty and graduate students in the University's Institute for Social Research, for example, are conducting research on new management systems required in computer-aided manufacturing environments and on three-dimensional visual display techniques that have potential for computer-aided manufacturing and design applications.

The university is also the temporary home of Michigan's new Industrial Technology Institute, a nonprofit corporation established in 1981 by the Governor's High Technology Task Force. The institute's goal is to become the national center for information, communication, and research on all aspects of

the "factory of the future," and its focus will be on practical research and industrial involvement.*

II. EDUCATION AND RESEARCH ACTIVITIES

College of Engineering

The College of Engineering is comprised of 10 departments which offer a total of 950 engineering courses. The college offers 13 undergraduate degree programs; and students who wish to combine the technically-oriented studies of the Engineering College with the humanities or physical, natural, or social sciences available in the College of Literature, Sciences and the Arts (LSA) may pursue a combined degree program enabling them to obtain "dual" bachelor's degrees in both colleges. Graduate studies include 26 programs leading to the master of science or master of science in engineering degree. Ph.D. candidates pursue independent investigation in a selected engineering field.

Goals

The college's goals in respect to teaching and research in integrated manufacturing must be seen in the light of its general educational objectives. With respect to undergraduate education, the college has two major goals, one traditional and one a response to the technological advances of recent years. The traditional objective is to provide undergraduates with a strong foundation in the fundamentals of engineering, mathematics and science. The second objective is to increase the "life-long learning skills" of students who will be working in a field in which the information has more than doubled since 1970.** Methods and procedures for achieving both of these objectives are discussed on pp. 6 to 17. After completing a general course of study in their freshman year, students may go into any one of 13 degree programs and may tailor specialized courses of study within existing degree programs. The emphasis on specialization increases as students proceed to the graduate level, where the instructional goal is to offer students "the

* See pp. 24-25.

** Joel Weldon, "Pilots Don't Have Rear View Mirrors."

opportunity to pursue special interests and to acquire a more thorough preparation for their first employment."*

While it does offer a number of senior-level courses focusing on computer-aided manufacturing theories and techniques, the College does not currently offer -- nor does it intend to offer -- an undergraduate program in integrated manufacturing. From the college's perspective, students specializing in this area should build on the skills and knowledge contained within existing engineering disciplines. The college's focus on computer-integrated (CIM) coursework is, therefore, aimed primarily at graduate-level engineering students. In 1981, the College established the Center for Robotics and Integrated Manufacturing (CRIM) with the objective of coordinating and expanding research and teaching activities in computer-based automation of industrial functions. A total of 45 graduate students are currently participating in CRIM-sponsored research projects, and faculty efforts to define and implement a manufacturing systems graduate program are now coming to fruition. While the structure of the program is as yet undecided, the college is committed to attracting the best of its graduate engineering students to integrated manufacturing studies.

The college's goals with respect to computer-aided design are broader and, at the same time, better defined than its integrated manufacturing curricula goals. The college offers a master's program in computer-aided design and has established a precise sequence of courses leading to the degree. Apart from this specialization, CAD coursework is an inherent part of almost all of the college's degree programs. The college's goal is to provide all of its students with a fundamental understanding and the basic skills needed to use the computer as a tool to facilitate engineering design in a broad spectrum of traditional disciplines.

Faculty

The majority of the 300 engineering faculty members are active in both teaching and research and many have distinguished themselves in both areas. While it is estimated that fewer than 20 percent have held full-time positions in industry, most faculty members have gained industrial experience through

* College of Engineering Bulletin, p. 111.

research and consultation on actual engineering projects. Each member of the teaching faculty is allotted 8 hours per week for consulting activities, and the College is giving serious consideration to instituting incentives to encourage greater faculty participation in industrial engineering projects. Forty faculty members from six departments are active in the integrated manufacturing research carried out under the auspices of CRIM, and most of these also teach courses dealing with some aspect of computer-aided manufacturing or design.

Facilities and Equipment

Until the fall of 1982, the engineering offices, classrooms and laboratories were far-flung, some existing on the main campus adjacent to downtown Ann Arbor and others on the North Campus 2 miles away. The College is now in the process of consolidating its physical space to about 15 buildings on the North Campus containing 7 major labs, at least 5 of which are used by students and faculty engaged in study or research in integrated manufacturing.

The University Computing Center, located on the North Campus, is a research and service facility for students, faculty, and research staff from a variety of colleges and departments. Central computing services are provided through an Amdahl 5860 mainframe computer, controlled by the Michigan Terminal System, which allows both conversational and batch processing. The laboratories used by engineering students and faculty engaged in computer aided manufacturing and design work contain terminals, graphical cathode ray tube (CRT) displays, and a broad array of superminicomputers and microcomputers which have access to the central computer. The Engineering College's CAD and CAM laboratories contain industrial and desk-top robots as well as small computers, CAD graphics stations, and terminals.

Undergraduate Engineering Education

Enrollment Trends

The Assistant Dean for Freshman Services reports that the number of women entering the college has increased and that the qualifications of the 1982 entering class are higher than those of last year's freshmen (median SAT scores jumped by 30 points). Of the 732 freshmen who enrolled in the 1982-83

academic year, 21 percent were women and 11 percent were minority students (precise figures for economically disadvantaged students were unavailable).

Another trend cited by the dean is a growing student focus on the occupational demands of the marketplace. More students than in the past come to his counseling staff to discuss vocational concerns, rather than academic preferences -- they want to know, for example, which degrees are most in demand by employers. The dean also notes increasing numbers of students transferring to the engineering school from the College of Literature, Science and the Arts (LSA) and that a number of these students cite the growing job opportunities for engineers as their reason for transferring from LSA disciplines, primarily mathematics and physics.

A number of freshmen have expressed interest in integrated manufacturing, specifically in robotics; but, according to the dean, many of these students have only a vague conception of what engineering education in the area of robotics entails. These students, in his view, are enamored of the mystique of robotics and are guided toward defining their specific area of interest (vision systems, for example) and entering a degree program which will provide them with the foundation of basic knowledge necessary to enable them to pursue their interest.

Curricula

All engineering students are introduced to digital computer concepts and systems in a required freshman course. At the end of their freshman year, students are encouraged to decide upon a specific departmental or interdisciplinary degree program. While most departments offer computer-aided design courses to their undergraduate students, courses in computer-aided manufacturing are normally open only to juniors, seniors or graduate students who have a solid foundation in a traditional engineering discipline (usually mechanical, industrial-and-operations, computer, electrical, materials or aerospace engineering) and who have completed specified prerequisites. At the junior and senior levels, students may elect many courses, some of which give an overview of integrated manufacturing, others of which explore its component systems and processes. The following list includes a sample of such courses open to upper division students.

Computer Aided Mechanical Design is an introduction to the use of the digital computer as a tool in engineering design and analysis of mechanical components and systems. The course includes sections on the use of application software and numerical methods associated with mechanical design.

Computer Control of Manufacturing Systems focuses on the basic elements of numerical control of metal processing systems, programming languages for point-to-point and contouring machines, and interaction between geometry and machinability decisions. The course includes laboratory experiments in optimizing part-programming and equipment utilization. Subjects covered include computerized numerical control, adaptive control, industrial robots, and flexible manufacturing systems.

Robot Applications teaches students basic concepts of organization and operation of microcomputer-controlled manipulators and application of computer-controlled robots in manufacturing and programmable automation. Students complete experiments in kinematics, manipulation, dynamics, trajectory planning, and programming.

Minicomputer Applications in Manufacturing presents applications of minicomputers to problems in process control, quality control, and mechanical analysis and also considers assembly level programming, input/output systems, and conversion of mechanical characteristics to digital data.

Computer Aided Design of Mechanical Systems deals with computer representation of mechanical parts and assemblies. Students study computer simulation of large displacement dynamics in two and three dimensions and analysis of three dimensional position, motion and force.

Design of Automatic Control Systems is an introduction to topics in control theory, presented in the context of control systems design. Students study topics such as state variable feedback, modal control, optimal control, and adaptive control.

Computer Aided Design Methods covers generalized mathematical modeling of engineering systems and methods of solution and simulation languages. Students learn about analysis methods in design, stress and finite element considerations, nonlinear programming, computational geometry, and other related topics.

Computer Graphics Applications includes the application of several software packages and display devices for engineering problem solving.

In the near future, new and modified courses now being developed as part of the college's proposed integrated manufacturing master's program should be available as elective coursework to undergraduates. Assistance in course selection and program planning is provided by faculty members who serve as program advisors and academic counselors.

Recent Emphasis on Tying Theory to Practical Skills and Work Experience on the Undergraduate Level

The majority of undergraduate courses in the College are theoretical in nature. Some applications courses are available to juniors and seniors, but, with the exception of senior level guided design courses, applied coursework is reserved for graduate students who have mastered the fundamentals.* College representatives believe that the college must continue to equip potential engineers with the theoretical basics underlying all engineering disciplines. The "information explosion," however, has led the college to emphasize another objective -- the development of life-long learning skills** that will enable undergraduates to build on their basics once they leave the university. In addition, the Engineering College introduced a cooperative education program in 1982 to provide practical work experience for undergraduates.

* Graduate coursework is not strictly "applied"; rather it involves the experimental application of advanced theoretical knowledge.

** "Lifelong learning" and "lifelong education" are terms employed by a large number of educators, training specialists, and industry representatives to emphasize what they see as the necessity for those in technical fields to engage in formal and informal continuing education in order to meet the "practitioner" requirements of changing technologies.

Building Life-Long Learning Skills. To encourage faculty members to help students develop life-long learning skills, the Associate Dean for Instruction has instituted an incentive program to provide funds, release time, and short summer assignments to faculty members to concentrate on the following three areas:

Assignments. Increased focus will be placed on homework assignments comprised of open-ended problems in which developing an appropriate approach is equally important to finding a solution. (Open-ended problems may be solved by a number of possible approaches, or they may not be soluble as defined in the assignment; the more traditional "close-ended problem" simply verifies the student's understanding of basic concepts.) By giving students the opportunity to practice defining, refining, and finding strategies for dealing with problems with no single solution, homework assignments can encourage creativity and develop skills that will be required in the workplace.

Laboratories. Funds will be made available to faculty members to develop many more laboratory experiments that require students to decide what the significant variables are and what the range of variability is (as opposed to experiments that simply demonstrate basic principles). In addition, the college is committed to upgrading the equipment and facilities in undergraduate laboratories.

Computer-aided learning. Release-time will be given to faculty members to develop interactive computing modules to increase the "divergent thinking capabilities" of the students. Interactive computing video disks can, for example, be programmed to present the student with branching pathways, some of which are dead-ends, some of which lead toward solutions to the problem simulated on the disk. This sort of computer-aided learning technique forces students to make decisions in gray areas and to deal with the frustration of problem definition and redefinition they will face in an industrial environment.

Complementing the three areas of concentration mentioned above is an increased emphasis on techniques based on the "guided design method" in which faculty members provide guidance (not pedagogic instruction) to students engaged in open-ended problem solving and interactive simulation exercises. Few of these techniques and methods are new, but they are difficult to implement on a college-wide scale because they are time-consuming and costly to develop and will result in some structural changes in undergraduate coursework. The teaching of design requires a significant amount of one-to-one teacher-student interaction, and therefore, smaller class sizes. The large undergraduate student body (over 4,000 students) and the heavy faculty teaching load make it neither possible nor desirable to structure all undergraduate classes as guided-design courses. The college has, however, made a commitment to identify those courses that are appropriate for the teaching of problem solving and design. College representatives plan to limit those courses to 20 to 40 students and to increase the enrollment of courses amenable to the lecture format. It is hoped that the obvious drawback of having enlarged lecture classes will be more than overcome by the increased student-teacher contact in the guided design classes.

To enhance the students' awareness of and facility in defining and refining open-ended problems, the college has also instituted senior fellowship awards which will provide full tuition to approximately 10 to 15 college seniors whose proposals for open-ended problem-solving experiments are selected by a committee made up of one faculty member and the most outstanding graduate student recipient from each department. This type of fellowship -- based on creative project proposals rather than on grades -- has a number of benefits: it encourages all students who compete for the awards to exercise creativity and self reliance in identifying and defining open-ended problems; it gives the recipients of the fellowships an opportunity to conduct a senior project focused on the refinement and solution of such problems; and it gives the graduate students on the committee experience in evaluating proposals.

Cooperative Education (Co-op) Program. The object of the cooperative education program is to provide participating students with actual industrial experience to help them integrate theory and practice and to give them an insider's perspective on the requirements of the workplace. Participating students alternate 4 months of study with 4 months of work throughout the year -- a procedure which usually extends the normal 4-year degree period by 1 year. Most students spend at least three work periods with a single firm, and the firm makes a commitment to provide them with progressively more demanding duties and responsibilities.

To date, only 54 students have been placed in work study arrangements, primarily because of the high cost of operating a large co-op program. It is estimated that a program for 150 students could cost the College up to \$100,000 per year (including salaries for three coordinators, an administrator, and clerical support, and funds to cover an estimated 10 percent increase in advisors' time and additional summer courses to accommodate students who work during one of the regular school terms). Also included in this estimate are the costs of developing a special seminar for co-op students; the seminar should deal with time management and long-range planning goals and provide students with an opportunity to discuss work-related problems. (It is likely that this course will be instituted as a senior seminar in the fall of 1984 for both co-op and regular students whether or not the problems with the co-op program are resolved.)

As of this writing, the college has not resolved its difficulties in funding the co-op program. One solution arrived at by college representatives -- that participating industries pay a fee which would be used to support the program -- has not been well-received by industries that have expressed general interest in the program. Although the college is exploring other strategies, it is possible that the newly initiated co-op program may not grow at the desired rate or be held back while the college uses its limited funds and faculty time to develop other activities.

Counseling

A large number of counseling services are available to engineering undergraduates. A staff of 10 counselors, under the direction of the Assistant Dean for Freshman Services, provide academic guidance to freshmen. During their sophomore year, when most students enroll in a specific engineering program, they are referred to program advisors who are responsible for academic counseling through graduation. Program advisors are assisted by faculty members serving as academic counselors who advise students on course electives. The Minority Engineering Program Office provides career and academic counseling to minority engineering students, and other counseling needs are met by the Counseling Center at the Institute for Human Adjustment, the university Counseling service, and the Office of Financial Aid. (Placement counseling is discussed below.)

Placement

The college operates an extremely active placement service which offers employment counseling, resume assistance, interview and job search preparation, and individual aid in such matters as salary negotiation. The placement office offers a "preselection service" to employers which makes available to them resumes of interested students. It also administers employment interviews on campus, posts job opportunities, and arranges for summer and short-term training positions.

No specific information on student placements in positions dealing with programmable automation was available. However, the director of placement has seen an upsurge of student interest in integrated manufacturing, and the college's annual report of engineering placement does provide an indicator of the type of employment accepted by engineering graduates. Of a total of 993 students awarded bachelor's degrees in the 1981-82 academic year, 819 registered for placement services for regular (as opposed to summer or part-time) employment. A total of 12,598 interviews of B.S., M.S. & Ph.D students were conducted in that year, and the average BS degree-holder who participated received over three job offers. Aerospace, electronics, and instruments industry representatives were the most active interviewers, followed by representatives from chemical firms, petroleum producers, utilities, research and development firms, and automotive and mechanical equipment producers. Of

376 students (both graduate and undergraduate) who returned questionnaires requesting information on the type of employment they accepted, by far the largest percentage, 36 percent, were employed in design and systems engineering; 25 percent were in research and development; and 15 percent were working in manufacturing and/or operations. The aerospace, electronics and instruments industry employed the largest number of graduates (26 percent). Second to that were automotive and mechanical equipment industries and research and/or consulting organizations (13 percent apiece), and electrical machinery and equipment placed third with 9 percent employment.* Most of the placements (45 percent) were in Michigan and other mid-western states; 23 percent were in the Eastern United States; 20 percent were in the West.**

Graduate Education and Research Activities

Of the 1,259 graduate students enrolled in the 1982 fall term, 45 engaged in research in some aspect of integrated manufacturing and 20 are enrolled in the Masters Degree program in Computer-Aided Design. The focal point for graduate studies in integrated manufacturing is the college's Center for Robotics and Integrated Manufacturing (CRIM) whose goal is the consolidation of research and the completion of instructional activities in robotics, computer engineering, manufacturing engineering, and information systems.

Instructional Activities and Curriculum Development

The College's plans to develop a coherent series of graduate courses leading to a specialization in integrated manufacturing have been accelerated by the establishment of CRIM. Even before the establishment of CRIM, the college faculty had been instituting new courses in integrated manufacturing and discussing various approaches to instruction in this area but major curriculum planning efforts were earmarked as a future activity. Now, however, engineering faculty members are working to 1) create a new master's degree program in integrated manufacturing and to design integrated manufacturing

* Relatively few student responses were received listing the employer's name. Based on a total of 163 student responses, the major employers for the 1981-82 academic year are, in order of number of hires: the Bell System, IBM, General Motors, Westinghouse Electric, and Ford Motor Company.
 ** The remaining 12 percent returned to school for graduate studies or entered the military services.

options within existing degree programs, and 2) determine what courses to include in the program and options, what courses must be modified, and what new courses must be created.

Graduate students currently engaged in integrated manufacturing coursework and research are helped by their advisors to create an instructional program from the large number of CIM-related courses already in existence. A student interested in pursuing coursework in robotic systems, for example, would take the lecture course in robot applications described on p. 7 and a laboratory course in robotics. Depending on his or her specific interest, he or she would also choose from among courses on subjects related to robotics. These include a course on artificial intelligence; two courses on image processing, computer vision, and image systems; a number of courses covering the modeling of mechanical devices; courses in automatic control systems; courses on integrated circuits and solid state sensors; mechanical design courses; a number of computer-aided design and computer graphics courses where students learn to use information from CAD databases to determine gripping positions, for example, or to create commercial vision systems; and courses in computer language theory and compiler construction.*

Center for Robotics and Integrated Manufacturing (CRIM)

CRIM was established in 1981 to coordinate integrated manufacturing teaching and research activities of six engineering departments: Electrical and Computer Engineering, Mechanical Engineering and Applied Mechanics, Industrial and Operations Engineering, Aerospace Engineering, Materials and Metallurgical Engineering, and Naval Architecture and Marine Engineering. Forty faculty members and a substantial number of graduate students are currently engaged in CRIM-sponsored research projects in the areas of manufacturing processes, product design, robotics, and factory management.

CRIM's approach to instruction and research in programmable automation technology is characterized by an emphasis on breadth and integration. Its interests cover the entire spectrum of automation technology, but its most active focus is on the integration of engineering, manufacturing, and management functions. Research activities are organized under three

* Compilers translate from one computer language to another.

divisions: Integrated Design and Manufacturing (IDM), Robot Systems, and Management Systems. An Integrated Manufacturing Systems Laboratory is now being established and will eventually serve all of the research divisions as a facility for testing research ideas in a simulated industrial setting. All of the instructional, research, and laboratory activities are coordinated by a steering committee made up of the chairmen of the engineering departments. Both the steering committee and an advisory committee (composed of industry, government, and university representatives) assist CRIM's director in relating the activities of the center to the needs and resources of industry, the university, and state and local governments.

Funding. CRIM received initial funding for its first 2 years of operation from the College of Engineering, the State of Michigan, National Science Foundation research grants, and industrial donations. More recently, CRIM received additional funds from the U.S. Air Force Office of Scientific Research (\$3.4 million) and the Calma Company (\$1.5 million). Future funding is expected to be provided by large industrial grants.

Laboratory Facilities. Apart from the proposed Integrated Manufacturing Laboratory, CRIM's researchers (both faculty and graduate students) have the use of numerous laboratories within the College. These include the Computer Aided Engineering Laboratory (CAEL), the Robot Systems Laboratory (RSL), the Computing Research Laboratory, a digital equipment prototype testing facility, and a number of departmental laboratories containing computer systems for data acquisition and automatic machine control and facilities for designing, fabricating, and testing integrated circuits and integrated robot sensors. A number of these laboratory facilities are now in the process of being consolidated and/or networked; others are being updated and expanded.

Representative Research Activities. All of the research conducted under the auspices of CRIM has a high degree of student involvement. At present, 45 graduate students are receiving financial support for their participation in research projects in integrated manufacturing, the largest of which -- an Air Force contract involving robotics research -- provides full stipends for 22 graduate students.

CRIM has a well-defined policy governing the type of research it will undertake. Research projects must be 1) long term (5 to 10 years) in nature; 2) in an area where technical success is uncertain; and 3) of potentially high technical or economic impact. Each of CRIM's three research divisions has identified broad areas of interest under which their research activities are concentrated:

Robot Systems Research is broadly concerned with the design of robots, robot control, and methods of interfacing with other robots and with other manufacturing devices and systems.

Integrated Design and Manufacturing Research emphasizes the integration of a product's design and its manufacture through a common computerized data base and concentrates its research activities in four major areas: manufacturing processes, control of process and systems, integrated design, and computer-aided manufacturing and measurements.

Management Systems Research focuses on the integration of manufacturing and control technology into operational production systems. Its primary areas of interest are analysis and design of new production facilities and the improvement of existing facilities; capital investment planning and cost control; organization and administration of production; man-machine interfaces and division of labor, and worker health and safety.

CRIM's acting director, who is also the college's associate dean for Research and Graduate Studies, describes a "model research program" which, it is hoped, will eventually characterize the research undertaken by faculty participating in CRIM and other faculty members as well. The faculty, in this model, would all participate in large "umbrella type" projects (which are seen as essential to interdisciplinary problem areas such as those addressed by CRIM) which would ideally involve technology transfer to industry. Each faculty member would also receive grants for research in a personal area of interest, at least a portion of which would complement the larger umbrella-type research project. Faculty would also develop ongoing working relationships with industry and interact with industrial representatives on a regular basis. Both the grants for the large, coordinated projects and the grants for the

individual research would include funding primarily for the participation of graduate students. While this model is, at this stage, primarily an ideal for the future in respect to College-wide research activity, some of the research currently conducted by CRIM is beginning to take on the look of the "model research program." An example is the Air Force Office of Scientific Research program on coordinating research in manufacturing science, in which faculty and students who work individually on such projects as developing tactile sensing devices for robots, experimenting with robot arm control, and developing computer vision systems to provide optical processing capabilities for inspection robots, devote periods of time ranging from 1 to 6 months on the coordinated project.

Industrial Affiliation. CRIM's acting director is in the process of forming the center's advisory committee, which will be comprised of chief executive officers of industrial firms and high-ranking government and university representatives. In addition to the center's advisory committee, each research division will establish industrial affiliates programs that will serve as channels of communication and interaction between faculty members and the technical staffs of participating industries. The Robot Systems Division was the first of the research groups to establish an affiliates program; as of May 1983, 14 companies (including General Motors, Devilbiss, the Dana Corporation, Lockheed, Intel, General Electric, and General Dynamics) had joined the program, five more were in the process of joining, and three others had expressed interest. Participating firms make unrestricted gifts of \$15,000 annually or \$25,000 biennially. The funds are used to buy laboratory equipment, * to support experimental activities leading to new research directions, to augment graduate student support-funding, to supplement funds supporting technicians and engineering personnel, and to augment departmental funds which bring in experts from across the country as workshop and seminar participants. In return for their support, the affiliated industries receive research reports and publications; a twice-yearly briefing providing up-to-date progress reports on the funded research and the opportunity to discuss research needs and problems with each other; contact with graduate students

* In some instances, equipment donations are accepted in lieu of the monetary donations, but only when such equipment fits into existing programs and facilities.

and continually updated information on participating students' research and progress toward degrees; and licenses for internal use of hardware or software developed under the affiliates program.

The major goal of the industrial affiliates programs is to encourage industrial participation and advice on long-term projects consistent with the research objectives of the university and which foster interaction and cross-fertilization between the industrial and academic communities. Additionally, some faculty members and graduate students participate in industry-funded projects in which shorter-term industrial goals are more closely addressed. Some of these projects are described below (Industry-Sponsored Research).

Master's Program in Computer Aided Design.

Apart from the college-wide instructional and research efforts conducted under the auspices of CRIM, the college offers a master's program in computer aided design which includes courses in computer hardware, computer software, simulation methods, data management, computer graphics, and applications of computer-oriented engineering design. Many students taking this program combine it with graduate coursework in other engineering degree programs and obtain dual master's degrees in CAD and a traditional engineering discipline.

Relationships with Industry.

Along with the CRIM advisory committee and the industrial affiliates programs operated by each of CRIM's three research divisions, the College of Engineering has its own advisory committee made up of local industry representatives. This committee advises informally and its primary function is to help the college to secure financial support and equipment for its various programs.

Industrial advice on curricular matters comes through several channels: advisory committees, workshops, seminars, conferences, and joint research projects. The most fruitful source of that advice on curricular matters is, however, feedback from college graduates working in industry. This traditional form of informal advice receives serious consideration by both individual faculty members and the college administration and frequently results in curricular modifications.

Industry-Sponsored Research. The majority of research projects are sponsored by National Science Foundation grants and college funds, and many cooperative projects are operated in conjunction with nonprofit organizations such as the Environmental Research Institute of Michigan. However, a growing number of faculty members and graduate students participate in research projects conducted for or by industry. One faculty member, for example, is working with Tech-S, a local firm, to develop microprocessor-based tools for industrial use. The actual research is conducted by graduate students from the College of Engineering, and Tech-S has also hired additional students who work under the joint supervision of the college faculty member and company researchers. Other college faculty and graduate students are working informally with researchers from Intel to perfect hardware and software of state-of-the-art equipment donated by the firm to the College's Robot Systems Laboratory. Other research is sponsored by Ford Motor Company, General Motors, TRW, Deere and Co., International Harvester, and Gerber, Inc., among others. In addition, a number of undergraduates and graduate students are working under the direction of three faculty members on a joint project -- "In-Process Sensing and Control for Computer-Aided Manufacturing" -- supported by a consortium of industries that includes Bendix-Warner & Swasey, Chrysler Corporation, Cincinnati Milacron, Eaton Corporation, General Electric, F. Joseph Lamb Company, and Xerox Corporation.

The research projects cited above are but a sample of the College's industry-sponsored research activity. Such industry-sponsored projects, according to the Associate Dean for Research and Graduate Studies, are likely to increase -- not only because funds from government and foundation sources are decreasing but because the College recognizes the ultimate laboratory for programmable automation research is in industry.

Faculty Consultation and Other Cooperative Arrangements with Industry. Apart from their research activities, faculty members also serve as industrial consultants. The College actively encourages these consulting activities by providing each faculty member eight hours per week for industrial consultation. College administrators have found that faculty members who are active in research and consulting bring up-to-date industrial knowledge into the classroom and are often the best teachers.* In many cases, however, their consulting activities do not provide faculty members with the sort of

industrial experience which helps them convey the atmosphere and needs of industry to their students (one faculty member described most academic consultation in industry as an "esoteric, ivory tower kind of experience"). Also, the academic system does not, at present, encourage industrial activity that does not result in research findings that can be published, and the avenue of advancement for young faculty members is still publication in professional journals. The college administration, however, is aware of this discrepancy in a field in which "industry is the ultimate laboratory" and is discussing ways of rectifying this situation. One proposed activity which may provide both faculty and students with real-world industrial experience is a project with TRW, now in the formative stages, which would allow faculty members to spend a term or a summer working at TRW. In the second stage of the project, graduate students chosen by the participating faculty would have a similar opportunity to work for the firm.

Continuing Education for Engineers. The College's continuing education activities take two major forms: summer conferences for working engineers and a microwave television network which broadcasts regular college courses to local industrial sites.

The summer conference program offers one-to-two week courses on specific topic areas for engineers, scientists, and managers with experience in industry, government, or education. In operation for almost thirty years, the summer conference program served 2,700 participants a year at its peak in the late sixties. Success, however, brought competition from other schools and from professional organizations like the Society of Manufacturing Engineers, and the program now attracts an average of 1,200 professionals each summer, while the number of courses offered dropped from 45 to 30. Nevertheless, the program has been maintained at its present size since the early seventies and continues to provide engineers from all sections of the United States with courses in state-of-the-art applications and new scientific and technological developments.*

* Conversations with both graduate and undergraduate students confirmed that students have this perception.

* In 1982, 71 percent of the attendees were from the Northeast (well over (continued)

The courses are planned and supervised by senior faculty members who usually invite experts from industry and government to participate as guest lecturers. The courses themselves are, of necessity, those which fill a need for the working professional; in recent years, courses in robotics (concepts, theory, and applications), mini- and microcomputers, and the finite element method in mechanical design were among the most well-attended and well-received.

The majority of summer conference courses are geared to the requirements of specific subject areas rather than to specific industries. For the past four years, however, the college has been operating a course specifically designed to serve the needs of a single firm: The Bendix Update Program is designed for Bendix engineers and engineering managers who, while they have a great deal of working experience, received their degrees before the technology explosion of the seventies and are lacking in computer skills. The program has four major goals: to reinforce the basic science and engineering backgrounds of the participants; to introduce new concepts and techniques; to provide fresh insights on creative problem solving techniques; and to increase motivation for self-education and personal development. Major topics include finite element analysis, control systems, microelectronics, computer graphics, a CAD/CAM overview, technical communication, and career management. While the program has been operating with a high degree of success for the past four years, it is unknown whether the recent acquisition of Bendix by Allied Corporation will affect the program.

The Instructional Television Network operated by the College now broadcasts approximately 10 courses each semester to industries in the Greater Detroit area.* The courses are chosen from among the regular senior- and graduate-level course offerings and carry regular university credits. In most instances, the participating firms pay regular university tuition fees (\$313 for undergraduate courses; \$520 for

half of those from Michigan); 15 percent from the Southwest; 8 percent from the Southeast; 1 percent from the Northwest; and the remainder from outside the continental U.S.

* Until fall 1983, when it dropped from two channels to one, the Network broadcast 20 courses per term.

graduate courses) for those employees who take the course. Participation in the program has decreased from 400 students in 1974 to 190 to 150 students in recent years, largely because of the withdrawal of the Chrysler Corporation from its once active participation. According to its interim director, the program is now at a decision point. In order to increase its lagging enrollment, it must focus more on industrial needs, and incentives must be offered to professors whose courses are televised. (At present, the only incentive is industrial exposure)

INTER-INSTITUTIONAL INSTRUCTIONAL AND RESEARCH ACTIVITIES

This section presents brief summaries of some of the activities related to computer-aided design and integrated manufacturing conducted by 1) engineering faculty in conjunction with the faculty of other colleges in the university and 2) faculty working in some of the numerous institutes supported by the university.

Interdisciplinary Studies and Research

The Urban Technological and Environmental Planning (UTEP) Program is supported by eight schools and colleges, including the College of Engineering, LSA, the School of Architecture and Urban Planning, the School of Business, and the School of Social Work. UTEP offers an area of concentration entitled Sociotechnological Systems (STS) open to students with master's degrees who have completed coursework equivalent to a bachelors degree in mathematics, engineering, or physical or natural science. The program's goal is to develop a greater understanding of the interaction between technological and social systems. Among the systems studied are automation, transportation, and communication.

Four UTEP faculty members and four Ph.D. students also participate in UTEP's Socioeconomic Aspects of Robotics and Integrated Manufacturing (SEARIM) project. The graduate students, who participate on a rotating basis, have backgrounds in engineering, social science, and social work; and the disciplines of the four principle researches are also split between engineering and social science. SEARIM's research focuses on cost-benefit analyses of integrated manufacturing systems and approaches the reprogrammable automation technology from the perspective of management to determine which

applications are most promising in terms of long- and short-term impacts. The SEARIM researchers are currently conducting a study of workers displaced by reprogrammable automation which focuses on the occupational categories of workers likely to be displaced and their educational background and occupational skills. A second phase of the study will attempt to determine what kind of retraining is most appropriate for workers in various occupational categories. A concurrent study focuses on the perceived problem of mid-level management's resistance to technological change.

Faculty from the Computer and Communication Sciences Department of the College of Literature, Science, and the Arts and from the Department of Electrical and Computer Engineering of the College of Engineering have recently submitted a proposal to the National Science Foundation (NSF) for funding to aid in the maintenance and expansion of a coordinated research program in experimental computer science and engineering. The project would be centered in the Computing Research Laboratory (CRL), an interdepartmental laboratory designed to encourage collaborative research in computer science and computer engineering. The proposal to NSF focuses on computer-based automation as a "rallying point for the research activities of the CRL" and as "an especially important focus for coordination of the (proposed) experimental research," in such areas as computer architecture, VLSI design, database systems, and software tools; and examples of existing and proposed coordinated research activities include computations structures for robotics, the development of hardware/software structure for controlling a general robot-based manufacturing cell (the specific focus here is on developing systems in which the hardware/software boundary is transparent).

The Center for Japanese Studies, an on-campus institute supported primarily by the university with assistance from U.S. and Japanese federal and private funding agencies, is currently administering a two-year research project comparing the automotive industries in the United States and Japan. The study, a comparative analysis of the product cycle in both countries, is an international, interdisciplinary effort conducted by engineers and sociologists from the University of Michigan, other American educational institutions, and Japan. The project is supported by General Motors, Ford, the UAW, and a number of U.S. automotive suppliers together with Toyota, Nissan, and Aisin Seiki.

The Institute for Social Research, (ISR) another of the university's research institutes, is providing support for research projects that approach the problems and potential of computer-aided design and manufacturing from human resource and psycho-physiological perspectives. One group of social scientists, for example, is studying the need for "flexible management systems" to accommodate the flexible manufacturing technologies represented by computer-aided design and manufacture. Another project, conducted by a perceptual psychologist and funded by the Office of Naval Research, explores three-dimensional visual display techniques that have application potential for the tele-operation of robots (i.e., human control of robots through remote manipulation) and for three-dimensional CAD displays. Graduate students participate in both of these projects.

The American Institutions Program in the College of Literature, Science and the Arts offers a course entitled "Industrial Organizations in Transition," which entails summer internships in industry for approximately 60 undergraduates.

These and other research and instructional activities offer University of Michigan students in engineering and other disciplines opportunities to explore aspects of integrated manufacturing from a variety of approaches. While many of these activities are conducted independently of each other, many faculty members and students from the various departments and institutes communicate on an informal basis and thereby bring the perspectives of many disciplines to bear on a wide range of problems and possible solutions.

III. THE INDUSTRIAL TECHNOLOGY INSTITUTE (ITI)

Although the Industrial Technology Institute is an independent entity, it maintains close ties to the University: the University's president sits on the Institute's three-member executive committee; the acting director of the Institute is on the faculty of the College of Engineering; and numerous faculty members from various departments and colleges have participated in ITI planning and development activities. ITI's first permanent director (formerly technical director of the Office of Naval Research) took office on August 1, 1983, and the Institute will occupy an existing building on the University's North Campus early in 1984. Regardless of the outcome of these determinations, it is assumed that University faculty will continue to

participate in the Institute's research on all aspects of integrated manufacturing. It is hoped that faculty members will work at the Institute on sabbatical leaves and/or make other arrangements to do Institute work on a part-time basis. The Institute will also set aside a certain number of positions for students. ITI was created with the intent of focusing on the application of existing technology; its spirit is, therefore, closer to industry than that of traditional research institutions, and a number of faculty members at the university look to ITI as a possible solution to the conflict in goals and orientation between industry and academia (See Section IV, pp. 29 to 33, for a more detailed discussion of this issue).

IV. EVALUATION OF PRESENT AND FUTURE EDUCATIONAL AND RESEARCH CAPACITY

College of Engineering representatives readily admit that the University of Michigan is a relatively late entrant into the field of integrated manufacturing and that it is, at present, behind institutions like Carnegie Mellon and Renault Polytechnic Institute in specific areas of integrated manufacturing education and research. They also point out, however, that Michigan has a broader base of students, faculty, and resources than the acknowledged leaders in the field and should, in the near future, be able to develop all the courses needed to form a coherent instructional program on the graduate level and to continue and expand its already considerable research activities.

Present Capacity: Strengths and Weaknesses

The University of Michigan's greatest strengths are the high calibre of its faculty and students, plus the diversity and the creative environment supportive of independent thinking and research it shares with other major universities.* Some of these strengths, however, carry attendant weaknesses. The University's diversity gives it the potential to bring together the talents, knowledge, and creativity of experts in many interrelated fields to form the interdisciplinary approach to education and research called for in integrated manufacturing; this same diversity, along with the independence also characteristic of the University, has the potential

* The College of Engineering is usually ranked fifth in the country for academic excellence and third in the number of degrees awarded.

to impede coordination. While interdisciplinary projects like those administered by CRIM, the Computer Research Laboratory, and the Center for Japanese Studies are indicative of the University's success in coordinating its intellectual, monetary, and equipment resources, a number of related projects and some curriculum development activities are conducted independently of each other and with only minimal communication among participants. This problem, like others that will be mentioned in the following pages, is not one which is amenable to quick and easy solutions. Faculty members already overburdened by teaching, research, and consulting have limited time to keep themselves apprised of -- let alone active in -- all of the activities which may have some bearing on their own research. This state of affairs indicates that solutions like the creation of a university-wide superstructure to increase coordination and communication would be difficult to achieve and uncertain of success. Furthermore, such solutions are beyond the University's present funding capacity.

Lack of Adequate Funding

The major problem affecting the University's capacity to educate its students and provide both students and faculty with a proper research environment is lack of adequate funds. As one graduate student pointed out, significant research in engineering -- especially in integrated manufacturing engineering -- has long passed the pencil-and-paper stage, and even the advanced computing equipment used in more recent years to run simulation studies is now far from adequate. What are needed now are test environments equipped with state-of-the-art machinery. Declining state, federal, and foundation funds combined with an increasing need for extremely expensive equipment that rapidly becomes outdated present a severe problem for all of the nation's educational institutions, and Michigan's schools are in tighter straits than many. Money is needed to hire new faculty in order to decrease the teaching load and to bring in needed computer engineering and software development skills; to upgrade and expand outmoded laboratory facilities;* to purchase computer-aided

* College representatives report that many industries are prepared to offer gifts of equipment. Computer-aided equipment, however, is extremely expensive to maintain, and the College must frequently turn down such donations because of lack of funds to cover maintenance contracts and the additional technical staff required.

and ancillary equipment and software; to hire technicians and engineers to maintain the new equipment; to facilitate curriculum development; to provide seed money for programs like the College of Engineering's cooperative education work study program; to provide additional support for graduate students and faculty members who cannot obtain adequate industrial, foundation, or agency funding for their research; and to retrain faculty members whose expertise lies in older technologies and who lack computer skills and knowledge.

Faculty Obsolescence, Overcrowded Classes, Outdated Laboratories, and Other Problems

The problem of faculty retraining goes beyond the provision of computer-related skills necessary to keep pace with technological advances. According to College spokesmen, many faculty members in need of retraining are older, tenured professors who are resistant to new techniques and are often the "least educated in modern industrial technology." A number of faculty members have spent their professional lives perfecting techniques that newer methods have thrown into obsolescence. Many have spent years working on techniques that can now be done by computers in a matter of seconds. This presents a hardship not only for the individuals involved but also for other faculty and students. One student cited what he perceived to be a trend -- "a general migration of those who haven't kept up with newly evolving technology to carry more of the undergraduate teaching load." Closely related to this is the fact, mentioned by teachers and students alike, that faculty who are most actively involved in innovative research are often the teachers most in demand, with the consequence that their classes are overcrowded while others are underenrolled. Undergraduates interviewed stated that they are deprived of personal contact with those professors whose advice and encouragement would be the most beneficial, and the active teachers and researchers have excessive demands made on their time. Students interviewed viewed the tenure system -- which allows tenured professors "to stay forever" -- as a constraint on creative teaching and research. These problems, of course, are typical of many large universities, and those engineering students interviewed who complained of overcrowded conditions, being educated as part of "a vast mass of students," and lack of access to professors and laboratory equipment were also quick to point out the benefits of a University of Michigan education.

These include the wide range of engineering coursework and degree programs, the "rigor" of the programs, and the excellence of most of the faculty members.

Potential and Partial Solutions. Nevertheless, the problems of overcrowded classes, outdated labs and faculty obsolescence are especially significant in an area like computer-aided manufacturing, and College of Engineering administrators are attempting to address these problems by hiring new faculty members (12 faculty members were added for the 1982-83 academic year and 25 more positions have been authorized for 1983-84), and upgrading and expanding many of the undergraduate laboratories. The college recently budgeted \$1 million for the upgrading of instructional laboratories. It is estimated, however, that \$21 million is needed to bring all College laboratories to state-of-the-art condition. In addition, the institution of the low enrollment guided design classes for undergraduates should help to solve the problem of limited teacher-student contact.

Problems Related to the Tenure System

While some tenured faculty face the problem of obsolescence, a number of younger, untenured faculty members face a different problem. Many college administrators and faculty recognize that actual industrial experience -- apart from consultation -- would be beneficial to faculty and that this benefit would be passed along to students in the form of increased information about industrial needs and practices. Under the present "publish or perish" system, however, there is little or no incentive for untenured faculty to take time from projects that result in publications. As one UM organization psychologist put it, there is still a single career ladder in the university; alternate paths -- work in industry, for example, or entrepreneurial activities resulting in corporate donations or government grants for research -- have not been formally recognized as acceptable for tenure-track faculty.

Suggested Solutions. This situation is also being addressed by the College of Engineering, which is considering ways of providing rewards for industrial experience. Methods under consideration are the development of industrial internship programs for faculty and incentives to encourage faculty members to use their sabbatical leaves to work in industry. One senior faculty member

points out, however, that until the College can find a way to incorporate such experience into the tenure granting system -- by, for example, giving "tenure credits" for work in industry -- few untenured professors are likely to choose it over the accepted publication-oriented route.

Alliance with Industry: Benefits and Problems

A closer alliance between the University, especially the College of Engineering, and industry may help to solve some of the problems mentioned above: the funding problem, the lack of adequate equipment, and the lack of proper incentives for faculty (tenured faculty in need of retraining and both tenured and untenured faculty who could benefit from industrial experience) could all be alleviated by industrial funds, equipment, and cooperation. Furthermore, the advances in integrated manufacturing made by industrial researchers make the potential benefits of such an alliance even more attractive to University researchers. A number of mechanisms that encourage industrial involvement are already in place: examples include the research, much of it industry-sponsored, coordinated by CRIM and the Computer Research Laboratory; the CRIM affiliates programs; and the continuing education and instructional television programs.

An industry-university alliance, however, presents problems of its own, the chief of which is the divergent research aims of industry and academia. The university is committed to long-term research (usually lasting five to ten years) that promises to have a significant impact on the technology or the economy, while the demands of industry usually require projects of lesser duration with specific production and/or design goals. While the interdisciplinary nature of current integrated manufacturing research calls for a "team approach" similar to that used in industrial settings, this is in many ways inimical to the traditional university approach which values self-determination and independent thinking. Other problems with the team approach to research in a university setting include the following: 1) active researchers who could contribute the most to large, coordinated projects are most often heavily committed to other projects; 2) junior faculty who must "publish or perish" have greater incentives to conduct independent research than to participate in large projects where their individual contribution is diffused; and 3) the necessity, in a large project, to hold frequent meetings

and to coordinate schedules entails a large amount of overhead for the College and places a heavy burden on faculty who have teaching, advising and other research commitments. The "model research program" proposed by the College's Associate Dean for Research and Graduate Studies (see pp. 16 to 17) is an attempt to overcome at least a portion of these problems. The creation of large "umbrella type" projects would serve the interdisciplinary needs of integrated manufacturing research and, hopefully, attract increased industrial participation. Smaller, individual projects would allow faculty to pursue independent research and give junior faculty members the opportunity to publish their own research results. In addition, laboratories, classroom facilities, and offices are now being consolidated and networked, which will make it easier for researchers -- both faculty and graduate students -- to communicate.

While the team approach has been successful in some CRIM projects, the associate dean anticipates that a long evolutionary period will be required for this approach to become a model for the college as a whole. The other major roadblock to industry-university cooperation -- the conflicting goals -- is perhaps less amenable to a true solution than to compromise on both sides. Such "compromises" have been made: the companies participating in the Robotics Industrial Affiliates Program, for example, have committed funds in support of long-term research projects; and in projects like those conducted with Tech-S and Intel (see pp. 18 to 19) university researchers are helping corporate partners to meet industrial goals.

Large scale corporate giving programs on the IBM model (IBM will award a total of \$50 million to universities across the country to develop new curricula in manufacturing technology) indicate a corporate awareness of the long-term benefits of helping universities to develop curricula and obtain the equipment necessary to train graduate engineers in interdisciplinary computer-aided manufacturing skills. The IBM proposal had a salutary effect on the College of Engineering even before the announcement of the grant recipients by giving the College the impetus to begin the work of integrated manufacturing curriculum planning sooner than was originally anticipated. Furthermore, discussions with IBM have helped faculty members participating in curriculum development to structure the new integrated manufacturing curriculum around the "systems approach" which will be needed to design and operate the large-scale

integrated manufacturing systems of the "factory of the future." As articulated by the College of Engineering faculty member responsible for coordinating the curriculum development effort, the systems approach involves looking at the entire process of manufacturing, rather than at discrete aspects of design or analysis. In the past, engineering faculty -- and, to a somewhat lesser extent, engineers working in industry -- became expert in narrowly defined areas, while the "process" was often taken care of by an accumulation of individuals with expertise in the parts making up the system. The new curriculum will develop engineers who are more "process-oriented" than in the past and who will learn to approach industrial manufacturing and design in a holistic manner.

Current Gains

While the instructional and research-related problems of the University are commensurate with its size, and while the magnitude of the problems indicates that quick and easy solutions will not be forthcoming, it should be stressed that the partial and interim solutions arrived at by the College have already produced results that lay the basis for future achievements. The College's commitment to introducing real-world problem-solving techniques in homework and laboratory assignments should help to prepare undergraduates to work in an industrial environment; the creation of limited-enrollment classes structured around open-ended problem solving should help to alleviate the undergraduate problem of lack of contact with professors; and the development of instructional software for computer-aided learning is not only potentially beneficial to students but could also be sold to increase College revenues. While approximately 45 graduate students have already completed coursework in integrated manufacturing, the new curricula under development promises to attract even more top calibre students to the area.

Laboratories are being consolidated, updated, and expanded. In addition, research organizations like CRIM and CRL not only give financial support and industrial exposure to graduate students, but they also encourage industrial participation and foster inter-collegiate communication. Furthermore, the summer seminars and televised courses for professional engineers open other channels for communication with industry while they help in the retraining of working engineers. The College is also exploring the possibility of creating

a profit-making corporation that would patent, implement, and sell the results of experimental research developed by university faculty to create equity capital to support further research and instructional activities.

Other institutes and colleges widen the range of the University's activities by bringing political, economic, and social perspectives to bear on the potential benefits and problems of integrated manufacturing in both the national and international contexts. Graduate students from a variety of disciplines therefore have the opportunity to benefit from, and often participate in, coursework and research of a truly interdisciplinary nature.

Future Capacity

All of the above-mentioned activities strengthen the future capacity of the University to provide instruction and research opportunities to engineering students. However, the relatively loose coordination between some of these activities -- especially between College of Engineering projects and the projects of other colleges and institutes in the University -- bring about problems of communication. The difficulties involved in implementing a team approach to research indicate that a system as diverse as the University of Michigan's may be slower to respond to the problems of industry and the needs of the economy than smaller organizations that place less of a premium on independence and self-determination in teaching and research. Smaller universities, universities in which only a few engineering departments are attempting to coordinate their activities, and universities which place less of an emphasis on high level research may be able to respond more rapidly. It is important to note, however, that the scope of Michigan's major objectives -- i.e., to create a broad-based integrated manufacturing master's program and to coordinate teaching and research activities of many departments -- may result in programs that lag behind those of other universities in terms of time but which may also be more comprehensive when all the pieces are finally in place. It should also be noted that the current achievements, especially in integrated manufacturing research, are reportedly of a high calibre.⁴

⁴ Hewitt H. Young, Summary Report on University Visitations Concerning Computer Aided Processes, College of Engineering and Applied Sciences, Arizona State University, November 1982, pp. 9-11.

Alliance with Industry

Considering the widely different needs and goals of industry and academic institutions which, like the University of Michigan, are committed to long term research, perhaps the ultimate solution to the problems of creating an industrial academic alliance lies in the potential of organizations like the Industrial Technology Institute (ITI) to bring together academic and industrial researchers in an environment that is neither academic nor private sector but a hybrid of the two. This approach has been successful in Germany where engineers from academia and industry work together on applied problems in the research facilities of the Fraunhofer Institute.* Whether ITI can fulfill this function remains to be seen. The individual chosen as its permanent director, the location decided upon for its permanent site, and its ability to attract new technology into the state will all have an impact on ITI's effectiveness; and ITI's effectiveness, in turn, may have a significant impact on the ability of researchers from the University of Michigan and other schools in the state to work with industry.

Undergraduate Education

The major problem in relation to the College of Engineering's future capacity is not graduate education and research, however, but undergraduate education. While the policy of reserving emphasis on computer-integrated manufacturing for the graduate level is, according to many educators and industry representatives, a sound one, the College could, perhaps, do more than it is doing at present to give undergraduate students more opportunities to engage in practical, industrially oriented work. The College has taken some steps in that direction by introducing real-world problem-solving techniques in homework and laboratory assignments and by establishing a cooperative education program. As noted on pp. 10 to 11, however, the co-op program is small (54 students). The new emphasis on real-world problem-solving, while it does improve on traditional homework and laboratory practices that simply demonstrate basic principles, is only a partial solution to the need for actual industrial exposure and experience. Other colleges and universities have addressed the need for "real-world problem-solving

* Information provided by Dr. Gerald Ross, Institute for Social Research.

experience" by soliciting actual industrial projects for upper-division undergraduates or by working with industries to create projects that simulate industrial conditions. Faculty members in those schools have discovered that the demands made by industrial projects introduce a large number of variables -- such as time-and-material restraints and design requirements imposed by fabrication and assembly processes -- that are difficult, if not impossible, to take into account in a completely academic environment where the students do not have an opportunity to see the actual fabricated results of their designs.

The introduction of project-oriented classes would require both industrial cooperation and an active commitment on the part of the College's already overstretched faculty and administrators to seek out and obtain such cooperation. The expansion of the cooperative education program requires additional funds, but funding is also needed to develop the various facilities and activities listed on pp. 26 to 27. The lack of undergraduate opportunities for exposure to actual or simulated industrial projects (opportunities that could add practical knowledge to the theoretical framework provided in the undergraduate coursework) appears to be the result of the high priority assigned to graduate coursework and research. Information provided by the Engineering College's placement service, however, indicates that the majority of the College's undergraduates go directly into industry.* While a strong research emphasis is, according to some engineering educators, one of the key factors for building an engineering college's future capacity to deliver high-quality education,** undergraduates planning for careers in integrated manufacturing must be aware that their major opportunities for applied coursework and projects exist on the graduate -- not the undergraduate -- level. Although College of Engineering counselors and advisors provide appropriate counseling and information to already-enrolled undergraduates preparing for engineering positions involving integrated manufacturing, a number of entering students may be unaware of the necessity of continuing

* No break-down by engineering department or discipline was available, so it is not possible to determine what percentage of those students graduated from departments involved in computer-integrated manufacturing on the graduate and upper-division levels. (Refer to pp. 12-13 for placement information).

** See J. G. Truxal and M. Visich, Jr., "Engineering Education and National Policy," *Science*, 8 October 1982, V. 218, n. 4568, p. 1.

their education at least through the masters' level in order to combine their theoretical knowledge with practical applications before going out into industry. Students with an interest in integrated manufacturing who do not plan on entering graduate school may be advised to evaluate Michigan's undergraduate programs in light of the programs of other universities with more opportunities for cooperative education or industrial project work on the undergraduate level; or it may be that the University of Michigan will be able to allocate more funds to undergraduate education in order to strengthen the co-op program and include project-oriented coursework in undergraduate studies.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

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Part C - Individual Education and Training Case Studies

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- C.5--MANUFACTURING ENGINEERING APPLICATIONS CENTER, WORCESTER, MA
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- C.8--UNIVERSITY OF MICHIGAN
- C.9--CADAM, INC.: CUSTOMER TRAINING IN COMPUTER-AIDED DESIGN
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- C.12--TEXAS INSTRUMENTS
- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
U.S. CONGRESS
MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

**C.9— CADAM, Inc.: Customer Training in Computer-
Aided Design**

This is an OTA Working Paper that has neither been reviewed nor
approved by the Technology Assessment Board

July 1984



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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

CADAM, INC.: CUSTOMER TRAINING IN COMPUTER-AIDED DESIGN

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

CADAM INC.

Customer Training in Computer-Aided Design

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CADAM INC.

Customer Training in Computer-Aided Design

SUMMARY

CADAM Inc, a subsidiary of Lockheed Corporation, produces computer-aided design and manufacturing (CAD/CAM) software, most of which is licensed to customers through IBM and other computer hardware firms. Customers may also buy CAD/CAM software directly from CADAM for use on systems that are "plug-compatible" with IBM systems.

CADAM provides basic computer graphics training free of charge to all customers who purchase software directly from the firm (two employees per customer) and charges \$1250 per student for basic training classes to all customers who license the software through IBM or other hardware distributors. Customers may also purchase the basic training in self-study packages for \$650 per kit. The software firm offers a more than 11 computer graphics programs, ranging from basic training in the CADAM system of computer-aided design to courses on 3-D piping and 3-D surfaces to numerical control programming to finite element modeling. In addition, CADAM offers a training consulting service designed to assist customers who have unique problems or special requirements. All training beyond CADAM Basic is delivered for a fee, which ranges from \$550 to \$3100 per student, depending on the length and complexity of the course. The majority of students are machinists, designers, drafters, and engineers.

While CADAM provides both in-plant training for all of its employees and what is referred to as "scope" training (training on the computer terminal in the operations required to use various CADAM® system ware packages),* this study will focus primarily on the customer training offered by the firm. When the firm was established in January 1982, its Lockheed Corporation founders committed themselves to providing "high quality training" which they saw as crucial to support the company goal of becoming a major developer and distributor of software in the CAD/CAM field. Today, the Training Department

*CADAM is a registered trademark and service mark of CADAM Inc.

-- which includes curriculum designers, internal trainers, and customer trainers -- accounts for 8 percent of all CADAM employees (an unusually high percentage), and the Director of training reports directly to the president of the firm. This, again, is unusual, since most training departments report through marketing, customer relations, or personnel.

Section I of this study discusses the history of the firm, the development of its training organization, the organizational structure and philosophy of CADAM® training, and the firm's relationship with educational institutions. Section II describes its training programs and methods and includes an in-depth description of the basic CADAM course and less detailed discussions of some of the other course offerings. Section III evaluates CADAM's present and future capacity to provide training in a variety of computer graphics applications.

I. CORPORATE BACKGROUND

History of CADAM Inc.

Although CADAM Inc. incorporated on January 1, 1982, is a young company, the history of the CADAM product goes back to 1967, when the original CADAM software was developed by Lockheed-California engineers to aid in the numerical control (N/C) programming and airframe design for Lockheed Aerospace Products. CADAM system software was originally created for use on IBM mainframes, but by the mid-seventies, Lockheed had also designed a CADAM package for use on Perkin Elmer mini-computers. By 1975, Lockheed was selling CADAM system software to users outside of the Lockheed Corporation. By 1978, in addition to marketing the system, IBM also adopted CADAM as its internal CAD/CAM software. IBM and Lockheed entered into a contractual arrangement in 1977 whereby IBM would market and distribute CADAM system software under the IBM installed user program (IUP), which makes software developed by IBM users available to the general public. Between 1976 and 1981, a large percentage of CADAM system software was licensed through IBM to customers who bought IBM-hardware/CADAM-software packages; and when it incorporated in 1982, CADAM Inc. continued the contractual relationship with IBM begun by its parent company, licensing the bulk of its software through IBM's installed user program. Today, IBM remains CADAM's largest distributor. Two other hardware producers

-- Perkin Elmer and Fujitsu (a major Japanese hardware producer) -- also distribute CADAM system software; a small percentage of CADAM's customers license software directly from the firm.

Company Characteristics

As of July 1983, CADAM employed approximately 280 people in its four major divisions: software development, marketing, training, and administration. Seventy-five percent of CADAM employees are in the software division; marketing and training have 10 percent each; and the remaining 5 percent are in administration. At present, the firm operates out of one facility, located near the Lockheed-California plant in Burbank, California. CADAM management plans to increase the software division by 40 employees during the latter part of 1983 and to maintain the training department at its current level.

The decision to incorporate what was once Lockheed's CADAM division was fueled by the perceived necessity of providing CADAM management with the flexibility it needed to operate in a fast-moving CAD/CAM marketplace with a wide variety of potential customers in aerospace, shipbuilding, automaking, architectural planning, and a number of other industries. Distinguishing CADAM from the majority of CAD software and software-hardware houses is the firm's concentration on developing software for mainframe CAD/CAM systems, specifically the IBM 370, 303X and 4300 series, rather than for turnkey, or stand-alone, systems utilizing mini-computers. According to company representatives, the advantages of mainframe as opposed to turnkey systems are increased data base capability and the ability to network CAD/CAM data bases (including the ability to transfer data between CAD and CAM systems), the ability to interface to other information systems, the greater growth capability of mainframes (to which over 100 terminals can be connected), greater telecommunications capabilities between far-flung terminals, and the increased speed, accuracy, and computing ability offered by 32-bit (mainframe)

as opposed to 16-bit (mini-computer) systems.* As a result of offering these features, CADAM Inc. believes it has a solution for an entire enterprise -- not merely a department or group.

According to CADAM's president, CAD/CAM technology is most profitably and productively used by firms that are not merely seeking to automate single processes, such as design drawings or N/C part programming, but are instead developing the capability to make their design and manufacturing processes into a single integrated system. CADAM management thus views the firm's major role as that of a systems catalyst, since they maintain that CAD/CAM systems can, when used by knowledgeable users, become the backbone of a computer integrated manufacturing system. In this sense, CADAM has two major markets: firms that use CAD or CAD/CAM systems for some processes, and, most important, firms that are in the process of developing integrated system capabilities. At present, CADAM has over 250 corporate users, including IBM (with almost 100 installations and several hundred terminals that make use of CADAM software), GM and other American firms, the majority of the largest Japanese automakers and shipbuilders, and firms throughout Western Europe, Canada, South Africa, and South America.

Training Organization and Philosophy

Lockheed-California began CADAM system training for employees in the late sixties, shortly after the CADAM product was developed; Lockheed instructors have been delivering CADAM system training since 1975, when software packages first began to be sold to outside users. As a company, then, CADAM Inc. had the advantage of starting out with a track record of training both customers and employees on a system that had been used in production environments for over 15 years; it also inherited 10 Lockheed-developed CADAM training programs and a number of experienced trainers.

* Many of the major turnkey vendors, however, are coming out with 32-bit minicomputers, which, according to Merrill Lynch's 1982 CAD/CAM Review and Outlook, "appear capable of stemming the inroads of mainframe computer competition" (p. 1). While mainframes have more CPU power and speed, the new 32-bit mini systems offer more extensive applications software and, except for "high-end large sophisticated needs," are superior to mainframes in price/performance comparisons (p. 9).

Top Priority Accorded to Training

According to CADAM's president, training was an integral part of the strategic business plan created prior to CADAM's incorporation. Convinced that customer support -- including training, curricular aids, and consulting services -- was a major requirement for success in the CAD/CAM field, CADAM management set out to establish a training department that would provide curricular materials and training of a consistently high quality. The new director of training and education, hired in November 1981, was given a mandate to produce quality training and to turn the training department into a profit center for the firm. As head of one of CADAM's four major divisions, the director of training reports directly to the president of the firm and has both flexibility (in structuring the training department, hiring trainers and program designers, and organizing and developing the training material) and accountability (for producing "quality product support" and for turning a profit).

While the training director had inherited a number of experienced Lockheed trainers and a number of training programs that had been taught successfully in the past, he found the written materials to be either not well developed or non-existent for some courses. According to the training director, CADAM training had been successful in Lockheed because the instructors were long-time practitioners on the CADAM system, many had natural training ability, and CADAM instruction was delivered to extremely small groups of trainees (one to four trainees per instructor, allowing each student a large amount of individual attention). However, the rising costs of providing training, CADAM's anticipated growth in the software field (which would result in an increased number of customers needing training), and the perceived need for consistently well-designed and well-delivered training indicated to the new director that some modifications should be made to Lockheed's methods of training to make it more suitable to the quality and profit requirements set by CADAM Inc's management.

Accordingly, in January 1982, he hired a manager of program design who had completed advanced graduate work at the University of Southern California's

(USC) Department of Instructional Technology.* The manager of program design hired other advanced graduate students, Ph. D.'s, and instructors from USC's Instructional Technology Department and created a staff of program designers. The program designers were given the responsibility of revising and restructuring the training courses CADAM had inherited from Lockheed and of designing new courses to teach new software programs.

Along with devising a consistent instructional approach for use in all CADAM training programs, the instructional design department was charged with restructuring the CADAM system's basic training and other selected courses (see pp. 13, 25) so that the curricular materials could either be delivered by CADAM instructors, by a customer's instructor, or be used as a self-study workbook. Such curricular materials were considered to have the following advantages: 1) reduced cost to both customers (who, if they chose, could buy the materials rather than pay for an instructor-delivered course) and CADAM, 2) increased consistency (i.e., replicability from instructor to instructor and uniform format from course to course), and 3) they could be used by students after the training course as refresher materials or as the basis for an in-plant course.

The work of revising existing curricula and developing new materials began in January, 1982. The Instructional Designers first completed interim revisions of the major CADAM system courses, including the Basic Terminal Operations course and the N/C Programming course. The object of the interim revision activity was to create structured written materials for courses that had previously been delivered in a variety of ways, depending on the individual methods developed by each instructor. Once the first revisions were completed, the designers began working on a full-scale revision of the basic course -- a lengthy nine-part procedure described in Appendix A. They also

* USC belongs to a consortium of universities (also including Michigan State, Syracuse University, the University of Indiana, and Florida State) that have developed fully-fledged graduate programs in Instructional Technology (IT). Originally developed in the late 'forties and early 'fifties as a means of systematizing training and educational programs, IT incorporates psychology, sociology, adult education and other disciplines to create instructional programs that take into account such factors as audience make-up, level of learning, educational levels and occupational background of the students, and their responses to the type of training or education provided (responses to learning to work on computers, for example).

used instructional design techniques to develop new courses, complete other interim revisions, and proceed with final revisions of other CADAM system courses. The work on the first prototype of the restructured basic course was begun in March 1982, and by October 1982, the prototype had been revised and tested three times. The final instructional materials were produced in December, 1982, and were available for use by CADAM instructors and customers in January, 1983. Other CADAM course revisions will follow a similar pattern.

The initial design work on the full-scale revision of the CADAM Basic course was done by an outside contractor, again from the University of Southern California. While most of the current program design work is done by in-house instructional designers, CADAM still occasionally makes use of USC-trained outside designers.

Each time a course is designated for revision, or when a new course must be developed, the manager of program design assigns one designer and one experienced trainer to work together on the course curriculum. The trainer's subject matter expertise and his or her knowledge of the hardware and software capabilities of the CADAM system is, of course, invaluable to the designer who must write the curriculum materials. The trainer, on the other hand, learns from the designer how Instructional Design courses are constructed, and this knowledge often helps the trainer to improve his/her teaching methods and delivery. Another added benefit is the double perspective (the instructor's approach and the designer's) which can be brought to bear on the course's design. Later in the design process, when the course is tested (see Appendix A, p. 4), a third viewpoint, that of the student, comes into play and is incorporated into the final product.

When developing training programs for new products or for updated software packages, the instructional designers work with the software developers and track the progress of software development or enhancement. The designers are therefore able to begin working on appropriate training programs before the software products are complete and can even suggest minor software

modifications based on training requirements and perceived user needs.*

CADAM management believes that this system of checks and balances -- involving cooperation between trainers and designers and between the software division and the training division, as well as accountability on the part of each division to the others and to top management -- produces a form of "quality assurance" whereby the product itself is designed with users and training requirements in mind, and the training effort supports the sale and use of the software.

Relationships with Educational Institutions

Aside from the Training Division's informal relationship with the University of Southern California's Instructional Technology Department, CADAM Inc. has numerous cooperative relationships with colleges and universities in California and throughout the country. In September, 1982, IBM announced its intention to award \$40 million worth of grants of hardware and of funds to university and college engineering schools to develop new curricula in manufacturing techniques. CADAM intends to supplement the IBM hardware donations with donations of software licenses.

Independently of the IBM grant, CADAM donates software to a number of universities and colleges to be used in teaching CAD/CAM fundamentals and occasionally provides CADAM training to selected colleges and universities for free or for a reduced rate. A more active relationship exists with a smaller number of schools to which CADAM also provides test releases of software. This arrangement gives students experience in solving software problems while, at the same time, aiding CADAM software analysts in debugging the software. With yet other institutions -- UCLA and Rensselaer Polytechnic Institute for example -- CADAM has engaged in joint development work. UCLA's Department of Manufacturing Engineering, for example, has received grants of IBM hardware and CADAM software, which it has integrated into the curriculum of three separate courses. CADAM and UCLA manufacturing engineering faculty and graduate students are also engaged in joint research to determine how to

* Suggestions provided by the training department have, for example, been incorporated into the N/C programming software to correct software difficulties experienced by users and trainers.

classify CADAM-made drawings into part families by using group technology* codes, with the ultimate object of developing an integrated manufacturing planning system. Another cooperative project conducted by UCLA aims to narrow the traditional communications gap between the design and manufacturing departments in industries by designing a "smart" CAD system that will monitor the design process and prompt the designer if he bypasses manufacturing considerations while designing a part, tool, or product. Another UCLA-CADAM project involves research into incorporating three-dimensional graphics capabilities into CADAM system software.

Other educational institutions with which CADAM maintains a close working relationship include Rensselaer Polytechnic Institute, Michigan Technological Institute, MIT, and California Polytechnic State University. Section III of this study discusses possible future projects with colleges and universities which may have a direct impact on CADAM system training itself and on the educational offerings of participating schools.

II. CADAM TRAINING

Summary

Aside from customer training, which will be described in detail in the following pages, CADAM also maintains a small internal training department to serve its own employees. All employees in the Software Division (program analysts, software developers, programmers) receive initial programming

* "Group Technology is linked to the concept that parts can be grouped into families, not only for design but for manufacturing purposes as well. . . . About 50 years ago, Group Technology emerged as a means of making it possible for design engineers to retrieve drawings, using a coding and classification system. . . . The use of the computer and the capturing of both design and manufacturing information in the code number made it possible to set up a data base which contained both design and manufacturing information. The design engineer could search for the information he required, and the manufacturing engineer could search the same data base for his information. . . . With a data base loaded with both design and manufacturing information, it was possible to extend the applications of Group Technology into other areas of Computer Aided Design and Computer Aided Manufacturing. In a sense, design and classification became a potential hub for the integration of Computer Aided Design and Computer Aided Manufacturing." Alexander Houtzeel, "Material Requirements Planning and Group Technology--Their Impact on the Manufacturing Industry," Organization for Industrial Research, Inc., pp. 289, 293-4.

training. The programmer training is designed to be about 50 percent self-instructional, so that students normally complete the training in from one to six months, depending on previous skills and knowledge and on individual learning speed. The internal trainers are there to monitor the instruction and to answer questions, while each student proceeds at his or her own pace. The internal training department is also responsible for developing and scheduling training programs on all new software products, for scheduling CAD terminal training for all CADAM employees who require it, for scheduling other types of training such as technical writing, and keeping employees informed of appropriate courses offered by local colleges and universities. (CADAM employees receive tuition reimbursement for higher education courses that are directly applicable to their professional duties.)

Internal as well as customer training curricula are developed by the program design staff, which also delivers seminars in program design for interested CADAM employees. CADAM system customer training is delivered primarily to designers, drafters, detailers, NC (numerical control) part program designers, and design and drafting department managers.

Training Division Staff

The training division consists of the director of training, the internal training group, the customer training group, the program designers, and three support personnel.

The training director, who was in computer sales for IBM from 1956 to 1969 and then moved into the industrial training field as an early employee of Tratech (a for-profit training firm) and a training consultant, combines experience in the computer and training fields with formal training as an accountant. The remainder of the professional staff in the training division is approximately equally split between employees with advanced degrees in instructional design, education, or the sciences and employees with practical experience working on and teaching the CADAM system.

The internal training staff currently consists of the manager for internal training and one trainer, but may soon be expanded by the addition of another instructor. The manager combines a higher degree (a doctorate in chemistry) with university teaching and broad experience in computer management. The internal trainer has a degree in education and experience in Lockheed as a programming trainer.

The manager of customer training is a long-time Lockheed employee (previously a drafter/designer) who was trained as a drafting designer on CADAM when it was first put into use in the late sixties. A trainer in the CADAM system since the early seventies, he became manager of customer training shortly after moving to CADAM Inc, from the Lockheed training department. Five of the six trainers combine production experience as CADAM system designers with experience as CADAM system trainers for Lockheed. The senior instructor has 20 years of training experience, 15 of which were spent training Lockheed employees and customers on the CADAM system.

The manager of the program design staff has completed advanced graduate work in the USC Instructional Technology Department and worked previously as a manager for another firm. The four program designers also have graduate and/or teaching experience in instructional technology at USC (one was an instructor, one an assistant professor), and one also has 10 years of industrial experience. All have had extensive experience in writing instructional curricula.

The difference in backgrounds between the trainers and the program designers reflects CADAM management's position that CADAM employees should specialize in what they do best -- that trainers should be practitioners with engineering or shopfloor experience and that curriculum developers should be trained communication specialists. The horizontal nature of CADAM's internal organization -- whereby trainers, program designers, and software developers are on parallel organizational levels -- is intended to encourage cooperation and to make all technical level employees accountable for portions of product development and support.

Training Facilities

Approximately half of all the customer training is delivered at CADAM's training facility, located at the CADAM plant and also used for employee training.* The training facility consists of four classrooms and a large computer laboratory, housing 12 graphics terminals (IBM 3250's) powered by an IBM 4341 Group II mainframe computer, which is shared with the marketing group.

* The remainder of the training is delivered on-site at the customer's location.

CUSTOMER TRAINING

Goals

The major goals of CADAM Inc. customer training are to provide a high level of training support to the customers and to do so on a profitable basis. Recognizing that the CADAM system cannot be effectively utilized by customers who have not been properly trained and that well-trained users are those most likely to be satisfied with the system and to expand their use of it, the training director established the program design department to support these goals with its own particular set of objectives. These objectives are to develop a complete set of training tools for each customer training program, to make those tools (written curricula, study guides, training guides, training aids, etc.) as consistent as possible both in content and delivery, to package appropriate courses as self-study programs to reduce training costs, and to develop new instructional programs to keep pace with software development and new software applications. The trainers' goals are to make sure that the students have a basic understanding of how the CADAM system operates and a specific understanding of the particular application package they are being trained to operate. (Specific goals for CADAM Basic Training are discussed on p. 14.)

Contractual Arrangements with Customers

When CADAM sells or leases software licenses directly to end-user customers, free Basic Terminal Operation training is provided for two customer employees. Intermediate Terminal Operation training and other CADAM training courses are then available to these customers for a fee.

Direct licensing makes up the smallest portion of CADAM sales. By far the largest distribution is through IBM, with which CADAM has three separate contracts: one for software licensing, one for software development and enhancement, and one for training. Under the current contracts, IBM markets both CADAM system software and CADAM system training, and the primary responsibility for the provision of training and other support is IBM's, which contracts with CADAM for actual training delivery. The responsibility for scheduling customers into training classes is also IBM's: CADAM provides IBM

with a projected 6-month schedule of training courses, and IBM schedules customers into available classes. The contractual relationship with Perkin Elmer and Fujitsu are somewhat different than with IBM.

Program Design

The principles of instructional design will eventually be used in all of CADAM's training programs. At present, two courses have been fully revised by the program designers: 1) CADAM Basic and 2) 3-D Piping, a new course designed for a software application program for the construction of pipe runs and spool diagrams. Four additional courses — Basic II, Analysis, CADAM Implementation, and CADAM Installation — will be ready by the third quarter of 1983. As applied by CADAM designers, instructional design provides a systematic approach to defining, developing, and evaluating training programs — an approach which attempts to combine flexibility with an organized structure. The instructional design system is usable both for creating new programs and for revising old training material.

The Instructional Design system used by CADAM designers is a nine-part process which, in the case of the revision of CADAM Basic training, took approximately nine months to complete. The process is broken down into three major functions — 1) definition of the problem or situation, 2) development, and 3) evaluation — each of which has three steps. Appendix A contains a detailed account of the program design process which is included to acquaint the reader with the scope of the instructional technology employed by CADAM.

Customer Training Programs

CADAM offers a total of 11 customer training programs plus a training consulting service. This section describes the Basic Terminal Operations course in detail and presents brief descriptions of other selected customer courses and the CADAM training consulting service.

Basic Terminal Operations

CADAM's basic training program is offered approximately twice a month. Previously a four-day course serving four students per class, CADAM Basic is now a five-day course which can accommodate 4 to 8 students and can be taught by CADAM instructors, trainers from customer firms, or can be used as a self-

study package. When delivered by CADAM trainers, the basic course is priced at \$1,250 per student; when sold as a self-study package, the cost is \$650 per study kit with additional workbooks priced at \$70 to \$150 each.

Course Goals. The major goals are to teach students to use the basic functions of the CADAM system to create engineering drawings and to understand the basic concepts and purposes of the system as applied to their own professional needs and work environments.

Prerequisites/Occupations Served. The single prerequisite for the course is the ability to read blueprints. The majority of students who have attended the course have been drafters, designers, engineers, NC part programmers, and managers of departments in which the system is installed. Originally used by industrial designers, the CADAM system is now also used by architectural designers, facilities planners engaged in floor and shelf layouts for markets, hospital supply houses and other firms, and by electricians and electrical designers who use the software for the design of printed circuit boards and wiring diagrams. The occupational categories of students enrolling in CADAM's Basic course are thus becoming more diverse as the applications of the system multiply, and there are plans to adjust the Basic course to reflect the changing audience.

Curriculum. The course consists of eight lessons, each of which builds the students' ability to operate the CADAM system by introducing them to the use of one or more of the system's function keys. (See Appendix 3 for illustrations of the CADAM system workstation and the function keyboard.) By use of the function keys, the operator calls up programs that enable him to create basic geometric shapes, to "edit" the geometry of his drawing--the "relimit" function key, for example, is used to trim or extend geometric elements--to indicate dimensions and to add notations, and to perform a variety of other operations. By the end of the course, the students will have learned the use of all of the function keys required for basic engineering drawings and will, in the process, have completed a series of practical exercises that result in a completed design of an industrial robot arm.

Lesson one begins with a general introduction, including a brief history of the CADAM system, its benefits, and the needs that it can fill; an

introduction to the workstation (including a hardware demonstration); and an overview of the general operation of the system. Following the introductory lecture/demonstration, the students complete an audio-tape-guided introductory lesson on the graphics terminal, in which they learn how to enter and exit the system ("login" and "logout") and to perform a few simple operations. They learn, for example, to perform the basic file manipulation required to start a new drawing, call an existing drawing to the screen, and file a drawing on the computer disk.

From lesson two onward, the students spend approximately 70 percent of their time working on the terminals and learning the system by means of practical exercises. In lesson two, they learn how to use the circle, line, and point function keys to create points, lines, and circles at specific locations; to use the offset key to create a line in a desired direction, for example, or to create a new concentric circle; and to perform procedures for moving, sizing, setting, and presetting the display on the screen by use of the "window" function key, which can focus in on a small section of a drawing or can widen its focus to present a full drawing on the screen (like a camera taking either close-ups or distance shots).

In subsequent lessons, the students learn to edit the basic geometry they have created (to create corners, to trim or extend elements, and to change the representation of an element from one line-type to another); to capture one or more elements for manipulation as a single entity or group, to analyze existing elements (lengths of lines, radii of circles, and relative distance between a pair of elements, for example); to create textual notes and symbols to accompany the drawing on the screen; to create auxiliary views; to plot hard copies of the drawing; and to perform other basic functions.

In the final lesson, the students also learn job planning techniques and how to create and use a standard library of drawings.*

* A standard library is a collection of drawings of standard parts or models used frequently by a specific firm. Once the original drawings are completed by the firm's designers, they are stored in the CADAM library file and can be called up and used (as is, or modified).

Instructional Methods.* The basic course is approximately 10 percent lecture (if delivered by an instructor), 20 percent in-class reading, and 70 percent practical experience on the terminal.

When used as a self-study course, the student workbook provides course content information and guides the student to consult the procedures guide which comes with the training package to help him/her complete exercises on the computer terminal. CADAM also provides instructions to managers to help them monitor the instruction and strongly recommends that, even when the course is delivered in the self-study mode, an experienced CADAM system user be on hand to answer questions and provide other assistance.

When used in a group learning environment, the workbook provides structure and support for the learning process, but the trainer becomes the primary resource by lecturing on course material, giving guidance to the students, and pacing the course to the students' speed.

The three critical elements in the instructional method -- stressed by the trainers and in the workbook itself -- are reading, planning, and careful performance of the exercises. The instructors encourage the students to read for conceptual understanding and to underline especially important sections. Planning is also an integral part of the instructional methodology. Each exercise is accompanied by a planning sheet for the students to complete. Once they read about the skills required to perform specific operations, they reinforce their understanding by planning how they will utilize those skills to complete the practical exercise. They then develop the skills by performing the exercise specified in the workbook.

Since each lesson is constructed of interlocking steps -- each of which presents new information and introduces new skills while reinforcing skills and information learned in previous steps -- students are strongly encouraged not to skip over any of the reading or planning phases.**

Training Materials. Each student receives a workbook, a Training Handbook and Procedures Guide, a magnetic tape which is fed into the computer and contains

* This section is adapted from the CADAM Manager's Guide.

** See p. 25 for customer response to the "reading-planning-performance" methodology.

student exercises, and audio tapes for the audio-guided segment in lesson one. In addition to the student material, the customer firm also receives a manager's guide.

Evaluation of Students. Each lesson of CADAM Basic contains a self-evaluation quiz to help students gauge their own progress in the course. Successful completion of the training does not depend on passing a final examination, but employers sometimes request the trainers to provide them with informal evaluations of the students to help them determine which students should be given the chief responsibility for operating the system at the customer's site.

Student Evaluation of the Course. Students are asked to complete written evaluations of the course, the instructor, and the training materials. On a seven-point scale, students rate the course objectives, handouts, visual aids, homework, course content, applicability to their own needs, and the instructor. They also provide comments on the usefulness of the material, their own ease or difficulty in absorbing it, and suggestions for improvement. After the interim revision of the course, ratings improved by up to two points, jumping from 5 or below to over six on the seven-point scale.*

Follow-up. At the present time, follow-up of program graduates is informal.** CADAM maintains a hot line which can be used by customers who experience software difficulties or run into operation problems they cannot solve, and a number of customers call the trainers directly for help with difficult problems.

* Since the final revision of the course was released shortly before the writing of this study, information on student evaluations of the final version of the course were not available.

** The Training Director intends to formalize the follow-up procedures once all of the customer courses have been revised.

Additional Training Courses

The majority of CADAM's customers sign up for additional training once they have completed CADAM Basic, either to increase their proficiency on the system or to learn how to operate the software programs for specific applications. Below are descriptions of the training programs most frequently requested by customers.

Management Overview.* This 3-day course is designed for managers in companies planning to install CADAM systems. The course objective is to assist the managers in charge of a CADAM installation by providing them with information on how to manage the system in their companies' environment. The course consists of limited hands-on terminal time plus lectures covering the capabilities of the CADAM system, basic CADAM operation, hardware requirements, application of CADAM within a company, the CADAM software modules,** use of the system as a tool to increase productivity, an overview of available CADAM training courses, and other topics pertaining to the management of the system.

Basic II Terminal Operations -- a 4-day course which is essentially a continuation of the Basic Terminal Operations course. The objective is to provide the students with detailed instruction and practice in constructing complex drawings and designs using such techniques as splines and flange angles.

* This course is in the process of complete redesign and rewriting using Instructional Design principles. It has been renamed "CADAM Implementation Course," and will be available in the third quarter of 1983.

** Customers normally purchase three or more software modules. To perform the most basic computer-aided design operations, for example, a customer would purchase the following software: 1) the CAD module, which is used to create, file, call-up, and modify basic geometry, 2) the data management module, used for archiving data, moving it on- and off-line, and other data management operations, and 3) the hard copy module, which controls the "plotting" of the drawing (obtaining a printed hard copy). There are, in all, 14 software modules. Customers intending to use CADAM for CAD/CAM operations would buy the CAD/CAM module (rather than the "CAD only" module) which is used for numerical control part programming design (see p. 28) plus a module for interfacing the CADAM software to post-processors using APT or Compiler 2 programming languages. All 14 software modules are described and discussed in the manager's overview.

Job Planning/On-the-Job Training -- a 4-day course teaching students how to operate the graphics terminal without supervision and to select, plan, and schedule design jobs. Students are instructed in the uses of the system, user needs, and format-use-and-content to help them in job planning. They are also aided by the instructor while working on sample problems from their own workload to help them increase their proficiency on the system.

Basic Numerical Control (N/C) Programming. The objective of this 5-day course is to provide the students with the skills and knowledge to produce multi-axis CADAM system N/C code for post-processors that generate programs to be used to run N/C machines (i.e., part program designers use the CADAM system to create tool path designs that are translated into computer codes which are then used to program computer-aided numerical control machines). This hands-on, terminal-oriented course is limited to three students per instructor and is paced according to the abilities of the individual students. Some of the topics covered include N/C operations and tools, part geometry considerations, and programming techniques. CADAM was developed as a production tool for N/C programming, as well as aircraft design, and many of today's customers purchase the software for N/C program design. This course is therefore a staple of the customer-training department's course offerings and is delivered approximately once a month.

Instructor Training. This 3-day training program provides the customers' trainers with the information and material required to teach the basic CADAM course. Prerequisites for this course are the CADAM Basic I and Basic II Terminal Operations courses and Job Planning/OJT. The material covered includes class organization, testing, lesson plans, training aids, and training techniques.

Training Consulting Service. This service gives the customer the opportunity to consult with a CADAM trainer prior to training and to create a customized training program tailored to specific needs. Whereas most firms that have installed the CADAM system for other than basic design use have sent employees to a series of CADAM courses -- Basic, Job Planning/OJT, and N/C Programming, for example -- the training consulting service provides customers with the

option of creating their own programs by piecing together segments of existing courses which best suit their requirements. This is a relatively new service, and only one customer (International Harvester) has made use of it. The program designed for International Harvester included the Basic I course (in full), those sections of the Basic II Terminal Operations course applicable to International Harvester's uses, and the Manager's Overview.

Students attending courses other than Basic Terminal Operations, Management Overview, or the customized course set up through the consulting service are requested to complete at least the basic course as a prerequisite. Depending on the specific course to be taken, other CADAM system courses may also be required. Evaluations by students and follow-up procedures are the same for all courses.*

Results

Number Trained

From January through September of 1982, CADAM instructors trained over 700 customer employees. That number, however, represents a small portion of trained CADAM system users, according to CADAM's training director. Because of the significant investment of time and money involved in sending employees to the CADAM training facility or bringing a CADAM trainer to the customer site, the majority of users send an "advance guard" who receive the training and return to train other employees.

Productivity Results

CADAM management is convinced that "the better the training product, the better the productivity at the customer's site." The firm's president, in fact, equates training with a form of quality assurance; the CADAM system, he says, is a tool that can be used to increase productivity by decreasing the time required for designers and drafters to do layouts, detailing, and (especially) changes in drawings. Adequate training, he adds, is necessary if that tool is to be used effectively.

* CADAM Inc. training programs not described in the preceding pages are the following: Advanced Numerical Control Programming, 3-D Surface, 3-D Piping, Finite Element Modeling, and Analysis Procedures.

While it is difficult to obtain quantifiable data on the results of the training as discrete from the results of system use, the subjective evaluations of CADAM customers and the improvement in the student ratings of the basic course on CADAM's own seven-point rating scale indicate that, for the most part, CADAM system training effectively supports the product. Nevertheless, a few customers have experienced some problems with the training. These are discussed on pp. 24-28 below.

Problems/Solutions

Organizational Difficulties: Personnel and Instructional Materials. The most significant problem faced by the CADAM Training Division was that of organizing the training staff and the training material to lower the cost and increase the consistency of the training itself. The creation of the Program Design Department freed the trainers from the responsibility of developing their own training material. The self-instructional training package developed for the basic course also frees CADAM from some of the service costs (providing an instructor to teach the course, etc.) and offers customers the option of purchasing training for slightly more than half the cost of the instructor-delivered course. While not all CADAM courses are amenable to the self-study format, the Training Division plans to package the Basic II Terminal Operations, Analysis Procedures, and 3-D Piping courses as self-study programs.

The solution to the problem of organizing the staff and materials, while decreasing the cost, did create another problem. Some of the instructors had difficulty accepting the change in focus in the revised basic course from the individual instructor's interpretation and explanation to the highly structured and print-centered instructional material. These instructors point out that the new course allows for less interaction between students and instructors. Other instructors, who have taught the basic course so frequently that they felt themselves growing stale, believe that the new basic course allows them to aid the students' progress with more ease than in the past, and these trainers appreciate the opportunity to apply their efforts to the more advanced courses. The solution to this problem of mixed instructor response to the new training method is being achieved through a give-and-take process of gradual accommodation. The instructors are required to learn new

techniques and methods which focus on facilitating the students' understanding of the print-centered material rather than on the instructors' own expertise and experience with the system. However, the division management points out that the instructors will be able to become experts in teaching specific aspects or applications of the system in advanced courses which will continue to require a large degree of teacher-student interaction. While the students lose some degree of personal interaction, they receive instructional materials which thoroughly cover each step of the process in a consistent manner and which can be used as readily accessible review material after the training is completed.

Trainee-Centered Problems. As with other training programs in computer-aided manufacturing and design, approximately 5 percent of trainees in the CADAM Basic course exhibit resistance to the training. CADAM Training Division representatives refer to the root cause of this resistance as "computer anxiety," a syndrome with two major aspects: the trainees' fear that they will be replaced by a computer and the corresponding fear that they will not be able to master the "monster" that is replacing them. In some instances, "computer anxiety" is accompanied by another negative response, labelled by CADAM trainers as the "It'll All Go By" syndrome (the belief that computer-aided design is a flash-in-the-pan trend which will never create significant changes in design work). Trainees who do show this type of resistance are in the minority and are, according to CADAM trainers, usually designers, engineers, or drafters nearing retirement age. While the growth of CAD/CAM has reduced the numbers of trainees who believe that "it'll all go by," "computer anxiety" remains a significant problem for some trainees. CADAM trainers address this problem by explaining that the system is a new tool that can only make their jobs easier. The student workbook for the basic course also helps the trainees to overcome their anxiety by, again, referring to the system as a tool rather than as a threat and introducing the students to the terminals within the first 8 hours of instruction by moving them into a hands-on exercise that is easy to execute and has minimal potential for failure. CADAM Inc. trainers estimate that fewer than one-quarter of the initially resistant trainees (two percent of the total student group) retain their resistance after the first two days of class and report that many initially resistant students have returned to take advanced courses. Approximately one

percent of all trainees fail to learn the system, not because of resistance to the training, but because of a "mental block," or inability to understand what is required to operate the system.

Another problem -- one experienced by the majority of trainees -- is that the basic course presents such a large volume of information that most students do not grasp all of it during the week-long course. Extension of the course into a second week was rejected as a solution because the customer firms can rarely spare their employees for that length of time. The new instructional materials are designed to address the problem of "overload" by presenting the information in the building block pattern (described on p. 3 of Appendix A) with built-in redundancies to reinforce knowledge of the previous steps. In addition, the new course material works as a reference guide once the training has been completed.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY TO MEET TRAINING NEEDS

Merrill Lynch states: "As users become more sophisticated, we envision a move toward general purpose mainframe computers at the high end application level for maximum performance and ability to do data base management. . . . This trend implies a change in character of some vendors toward being CAD/CAM system integrators."* CADAM's orientation to the systems integration approach, and CADAM management's belief that training is an integral element in that approach, may be the key to the future potential of both the software product and the training that supports it. However, it should be noted that under its Installed User Program IBM also markets CAD software produced by other firms. Two of those software packages -- CAEDS, developed by Structural Dynamics Research Corp., and Circuit Board Design System, developed by a Canadian firm -- address specific CAD applications and not the broad design and manufacturing market aimed at by CADAM; but the third package -- CATIA, developed by Dassault Systems in France -- does, according to an IBM representative, have some potential "overlap" with CADAM Inc.'s software

* CAD/CAM Review and Outlook, 1981, p. 2. The Merrill Lynch 1982 CAD/CAM Review and Outlook's user survey, however, found that among the overall disadvantages of mainframe systems are insufficient software and support, high initial expenses, and the fact that the entire system goes down when the CPU does.

applications. In addition, IBM also markets a CADAM training package, called a "Graphics Training Aid," developed by Westinghouse's Industry Motor Division in Roundtree, Texas. The Graphics Training Aid was purchased by approximately 50 companies in 1982, primarily those intending to set up their own internal CADAM training operations. While neither Westinghouse nor IBM views the Westinghouse Training Aid, which most buyers purchase as a self-study package, as being in direct competition with CADAM system training, the Westinghouse package does give the customer the option of purchasing training other than that supplied by CADAM Inc. Furthermore, CADAM training is also sold by independent engineering and consulting firms -- one of which, according to one customer interviewed, delivered two weeks of "excellent" training to his employees. The "partnership" with IBM, then, does not give CADAM Inc. a monopoly on IBM's hardware customers nor does the firm's own training department have a monopoly on CADAM training.

Customer Evaluations

Six CADAM Inc. customers, most of whom had received training after either the interim or final revisions of CADAM Basic had been completed, were interviewed. Most of those interviewed represented medium- to large-sized firms which had previous experience with either the CADAM system or other computer-aided design systems, and some are actively engaged in networking CAD and CAM capabilities. Responses to a request for an overall evaluation of the training -- including content, delivery, and applicability to specific company needs -- ranged from "reasonable" and "good" to "excellent." One customer, who had received CADAM Inc. training in January 1982, went to an outside consultant for further CADAM training a few months later and returned to CADAM Inc. at the end of 1982 for more training, said that training and other support supplied by CADAM Inc. was inadequate in January but had shown "great improvement" and "greatly increased attention to detail" by the end of the year.

Instructional Material

Evaluations of the newly designed student workbook ranged from "good, but limited"* to "very good," and the majority of the respondents rated the Training Handbook and Procedures Guide as very good. Specific criticisms of the training material were that some sections appeared to have been written from a software programmer's -- rather than a designer's or engineer's -- point of view, that the specific application completed by the students during the week-long course -- designing an industrial robot called "CADMAN" -- was "trite" and "unrealistic," and that the training material still showed signs of its Lockheed origins and contained certain operations and applications that may be "good for Lockheed, but not necessarily good for the outside world." Specific commendations were that the exercise planning sections built into the workbook (see p. 16) were helpful, and that the "educator's" touch seen in the attention to the structure of the training program and the instructional methods employed was a definite plus. Two customers who had undergone CADAM system training both before and after the revision of the training materials noted a great deal of improvement in the documentation and believed that CADAM Inc. had done "a good job of upgrading" its training material.

While four of the six customers were either considering, planning on buying, or had already purchased the training as a self-study package, only one had completed the self-study course at the present writing. That customer was "very satisfied" with the self-study course and liked the flexibility of being

* The limitation, according to this customer, is that the workbook took students through one specific application (the construction of an industrial robot arm) which, in his case, did not pertain to the application uses of his firm. This customer believed that, while the basic functions of the system were covered in the workbook, the training program would have been enhanced if students had been exposed to other applications and operations. It should be noted that one of the long-term goals of CADAM's training division is to develop training packages addressing specific applications but that the work of refining and revising already-existing training programs is, at present, taking precedence.

able to structure the training to suit the students' needs and work schedules.^o

All of the customers who have bought or are considering the self-study option planned on designating one or more trained CADAM users as facilitators of the training, and two firms are in the process of setting up internal CADAM system training programs. All of these customers are following CADAM's suggestion to designate a facilitator who can answer questions and assist the students with problems. One firm, which has sent employees to CADAM Inc. for classroom training and has also purchased the self-study package, stated that the self-study format was easy to follow and flexible enough to enable its internal training department to expand the course to one month of training for a few hours a day, which it found more amenable to its own operations than a condensed one-week program.

Trainers

Evaluations of the instructors varied from customer to customer and from trainer to trainer. One department manager, who had taken the basic course himself, and whose employees had been trained by four CADAM Inc. instructors, said that one instructor was excellent, two were above average, and one "was in the wrong business." One customer found the trainers to be "quite capable," and another -- whose employees had taken CADAM system training early in 1982 and again at the end of the year -- noted an improvement in the trainers' attitude, improved lectures, and an increased attention to detail in the later courses. One customer felt that his instructor gave overly complete answers to questions and did not allow the students the opportunity to think for themselves -- that is, instead of pointing out the proper procedure and allowing the students to complete an exercise on their own, the instructor led them through it in a step-by-step manner. Another problem attributed by customers to the trainers could also be partially due to the difficulties that some CADAM Inc. instructors are having in adjusting to the new highly-

* The self-study customer has assigned a trained CADAM system user to "facilitate" the students' coursework. Both the customer and CADAM representatives believe that a trained facilitator provides the necessary personal contact to make sure that students benefit from the self-study course.

structured material. Two customers said that the trainers occasionally refused to answer questions relating to advanced applications and instead encouraged them to return to take advanced CADAM system courses. While, from the trainers' point of view, long discussions of advanced applications disrupts the flow of the tightly structured basic course, from the customers' viewpoint, the trainers' refusal to go beyond the basic course indicated a lack of flexibility and lack of attentiveness to the customers' needs.

Benefits

One customer -- who had made a three-year study of the CAD market before purchasing a system -- said that the real benefit of the training delivered by the CADAM Training Department, as opposed to CADAM training delivered by other vendors, is that the trainees learn how to make the most efficient use of the system in the shortest period of time. The majority of the customers said that, after completing formal CADAM system training programs, they felt well prepared to embark on the most significant portion of the training -- the period directly following the formal course when the systems are used for actual production work. During this two- to four-week period, most of those interviewed reported that their new CADAM system operators got "up to speed" (i.e., produced designs at rates which matched or exceeded manual drawing times) even faster than anticipated. Those who had purchased or were considering purchasing the self-study packages felt that this new option was a tremendous benefit, primarily because of the perceived need for on-going internal CAD training.

Problems

Aside from the problems mentioned in the preceding pages of this section, the most frequently articulated problem was that the terminals at the CADAM Inc. training center occasionally went "down" or had poor response-time. (None of the customers interviewed have had equipment problems at their own installations, however, and many reported "incredibly quick" response times averaging 0.15 second.) While the equipment problems at CADAM -- which are currently being addressed -- do not reflect on the trainers or on the training materials, they did create an atmosphere of frustration which colored the trainees' perception of the training course. One customer, whose firm is

located in the Southeast, has had numerous problems with the CADAM hotline, which, he claims, is often inaccessible to Eastern customers because it only operates during business hours on Pacific time. This customer has lodged a formal request to encourage CADAM to extend its hotline hours to accommodate customers located in other time zones.

All of those interviewed agreed that CADAM Inc. training is extremely expensive relative to customer training provided by the majority of other computer-aided-design firms. While most accepted the high cost of the training as either a necessary evil or as the price of learning to be effective users of the CADAM system, one customer labelled the price of the training as "outrageous -- highway robbery." Although most of those interviewed thought that the cost of the self-study packages (\$650 per kit, as opposed to \$1,250 per student for the Basic course) makes CADAM Inc. training a more reasonable investment, one believed that even the self-study package was "twice what it should be."

Training for Profit: Pros and Cons

CADAM's training director points out that, while many hardware (and hardware/software) firms provide training free of charge to their customers -- or at rates far below those charged by CADAM -- by, in essence, folding the cost of training into the hardware or software prices -- CADAM's procedure of pricing training to cover the operating and development costs of the training division creates certain benefits for both the customer and the training deliverer. For one, customers get what they pay for -- that is, customers who require little or no training are not subsidizing the training of other customers. Secondly, he says, because training costs are frequently buried in equipment or operating costs, most companies do not recognize that good training is expensive to develop and deliver. It is for this reason, he believes, that training is often "too little and too late" and is often among the first support functions to be cut back during economic downturns; so that, along with recognizing that training is a necessity if sophisticated equipment is to be used effectively, company management must also recognize the actual costs of creating and maintaining training functions.

The status of training within CADAM's organizational structure -- the fact that the training function is the sole responsibility of one of the four major

divisions -- indicates CADAM management's recognition that training itself is of pivotal importance in the CAD/CAM field. The scope and degree of CADAM's commitment to training is possibly unique in some respects. Certainly the relative size of the Training Division (8 percent of the firm's employees) is unusual*, as is the fact that the training director reports directly to the president of the firm. Also unusual is the degree of flexibility and responsibility accorded to the Training Division. The division is responsible for providing "quality" training to support the software product and for making a profit. Also, it is given the flexibility, the resources, and the communicative channel with the product development department necessary to fulfill that responsibility. A comment by a Training Division representative provides a cogent description of the firm's approach to training in general: "We're trying to turn the old situation of training departments around. Most training departments are not given enough responsibility and accountability and have a subservient position in the company, reporting through many levels of bureaucracy. In a high tech field, training can no longer be handled in a subsidiary, low-level, low-priority fashion -- it's too important. Things are too volatile and they change too fast."

By designating the Training Division as a profit-center and by providing it with the resources and organizational support to produce a well-designed training product, CADAM management has made an investment in the training itself. This means that the training product must be high quality if the firm is to realize a return on its investment indirectly (in terms of product support) and in terms of direct profit from the training charges. The profit realized from the training is used to pay the Training Division's operating costs and to fund development of new training programs and the refinement of the already-existing courses.

As a profit-making entity whose training product entails a great deal of expense -- both to the customer and to CADAM -- the training division runs the risk of, as one customer put it, pricing itself out of the training market. And when high prices are combined with a reluctance on the trainers' part to go beyond the contents of the basic course when students ask about advanced applications, the CADAM training division also runs the risk of giving some

* It should be noted, however, that the ratio of training division personnel to other CADAM employees would be more difficult to achieve in a larger firm.

customers the impression that their specific needs will be attended to only in so far as they do not extend into areas covered by further training, i.e., which entail further purchases of training.

On the other hand, statements by trainers in some user firms support the assertion of CADAM's training director that the common practice of burying training costs in operating or other expenses keeps management unaware of the real costs of providing training. It is possible that what is perceived as an "outrageous" training cost actually reflects a reality that most industries are not used to seeing. The Training Division's cognizance of the need to lower training costs while maintaining quality resulted in the development of the self-study packages that both reduce the cost and enable customers to train future generations of users with the same instructional material. It remains to be seen whether the self-study package will solve the problem of high cost.

Program Design Staff and Methodology

While it is outside the confines of this study to engage in a comparison of Instructional Technology and other training methodologies, CADAM's use of Instructional Technology and its creation of a department specifically devoted to program design are worthy of comment. Although the process of integrating two such essentially diverse groups as the program designers (whose backgrounds are primarily academic) and the trainers (whose backgrounds are in practical engineering, design, and machine shop operation) continues to be difficult, the combination of skills and background may, in the long run, prove effective in providing a double perspective on the design of the training programs. The improvement in the course evaluations filled out by CADAM trainees in recent months and the customer comments reported on pp. 24-28 of this study are indications that the quality of the courses has been enhanced since the creation of the program design department.

During the last year, the disparity between the program designers and the trainers has decreased as the designers built up their practical knowledge of the system and the trainers learned about the methods and techniques of curriculum design. Furthermore, the existence of the program design department takes the burden of developing coursework off the instructors, provides them with new teaching methods, and enables the firm to invest more

time in developing, testing, and evaluating its training programs. In addition -- whether or not the actual methods of Instructional Technology prove to be the most appropriate ones for the design of skill-training programs -- the Training Division's use of an internally coherent and systematic instructional methodology which attempts to take into account the wide variety of cognitive, sociological, psychomotor, and psychological factors that go into building a training program is noteworthy in-and-of itself. While ultimate success will to some degree depend on the division's readiness to modify those techniques and concepts that do not work out in practice, its use of an instructional design tool as comprehensive as Instructional Technology has the potential to enhance its capacity to provide training to meet the growing needs of CADAM users.

CADAM's use of Instructional Technology to take into account the multiplicity of factors involved in constructing a training programs is paralleled by the Training Division's attempt to address all of the training factors involved when a CADAM system is installed in a customer's facility. The customer company's management is encouraged to attend the Management Overview course before the system is installed, and the basic course comes with a Manager's Guide that aids the manager responsible for scheduling and tracking self-study training. CADAM's Training Consulting Service offers customers the opportunity to structure their own training packages specifically suited to their needs. Although some customers have experienced difficulties in using the CADAM hotline, this service does provide an avenue for customers to receive assistance after the training is completed.

Future Capacity

The Training Division's most pressing future commitments are to 1) complete the work of revising the currently offered training programs, 2) package appropriate courses as self-study programs, and 3) keep pace with the Software Division by creating new courses for newly developed software applications. Once these major commitments are well under way, the division can proceed with plans to develop courses in such areas as CAD/CAM data base management and courses geared to the use of CADAM in specific production and design environments such as architecture, aerospace, and shipbuilding.

CADAM's training director hopes to establish mutually beneficial relationships with selected colleges and universities to achieve the latter objective by, for example, working with schools that excel in architectural planning to develop a CADAM training program for architectural designers. In return for their assistance in developing the training, the schools would receive CADAM software licenses and possible additional grants, CADAM training, or licenses to use CADAM training material for instructional purposes. The training director would also consider the possibility of aiding local colleges and universities by making the facilities at the CADAM customer training center available for use by their students if the problem of equipment security could be solved, if the school could provide instructors capable of insuring that the equipment would be well used, and if CADAM were reimbursed for equipment costs. Both of these potential activities -- the first a more realistic future possibility than the second -- serve a double purpose. The first would increase the scope of CADAM training while providing educational institutions with software and expertise in computer-aided design in relation to their subject matter expertise. The second would increase the number of trained CADAM operators entering design departments while providing schools with sorely needed labs and equipment.

The Training Division is also in a position to have an indirect influence on a broader spectrum of training and educational activities. The informal association between the program design department and the University of Southern California's Department of Instructional Technology can and does add to the university's information on the successes and failures of its methodologies in a specific industrial context. Also, CADAM's training director has given a presentation of how the theory of Instructional Technology works in practice at last year's "Cue" meeting (the CADAM Users' Exchange). At the same meeting, the Westinghouse representative who had developed the Graphics Training Aid gave a presentation on the importance of training in the computer graphics world. Gatherings such as the Cue meetings, while they may in some sense be examples of preaching to the initiated, do provide a forum for discussion of instructional approaches and methods by trainers and users alike and raise industrial awareness of the need for training in general.

The firm's capacity to meet the direct training needs of future CADAM customers will depend on its ability to maintain its gains in improving the quality of the courses and to develop new courses while keeping its prices within reasonable limits. CADAM's approach to training presents an interesting conundrum. On one hand, CADAM illustrates that significant time and money spent to make training a "first priority" can be seen as investments rather than as begrudged expenses. The firm also illustrates that the investment of those resources in well-designed and adequately tested training can increase productivity and profit. On the other hand, it may be a matter of questionable prudence for CADAM Inc. to be among the few software providers pricing their training "realistically." Can they "educate" the entire population of users as to the actual costs of training, or will other training vendors who offer "CADAM" instruction at a lower price deprive the Training Division of significant numbers of students?

Although CADAM training appears to be of a high standard, it also appears to some customers that CADAM's packaging of training as a high priced commodity sometimes impinges on its overall effectiveness by limiting the information available to trainees in the basic classes. It would seem then, that there is an attitudinal problem on the part of both the recipients and the provider of training, each with his own expectations of the proper form of training and the behavior of trainers. More explicit communication between the trainers -- who must use the limited time at their disposal to present a great deal of material in a systematic fashion -- and the customers -- who have varying needs which may not always mesh with the highly structured Basic course -- would ameliorate this difficulty.

APPENDIX A

INSTRUCTIONAL DESIGN SYSTEM EMPLOYED BY CADAM INC.

The following description relates specifically to the designer's approach in revising CADAM Inc.'s basic terminal operations course. It may, however, be taken as a model for other CADAM system course development and revision activities.

Definition. The three steps making up the definition function are
1) identification of the problem or situation, 2) analysis of the setting, and
3) organization of the development team.

Step 1. The following problems with the old CADAM Basic course were identified: the student fee (at that time, \$1,200) was too high, individual instructors used varying methods of presentation and provided students with varying coverage of the material, and the written material was incomplete and, according to the new training director "unprofessional."

Step 2. The first step toward the solution of the problems identified in step one involved an analysis of the setting--the training and work environment in which the CADAM system is used. The analysis took into consideration the conditions under which training and production take place, limitations of the setting, tools required, resources, and the backgrounds, interests and abilities of the students. The course revision was intended to address the problems of high cost and inconsistent delivery and coverage, and the need to serve students with diverse backgrounds and capabilities. The most pertinent factors in the analysis were therefore the physical conditions of the training environment (i.e., how long students could be productive at the terminal, etc.), requirements for teaching double the number of students (8 instead of 4) while maintaining quality, the differing needs of customers, the fact that the training would take place either at the CADAM training

* The director of training explains that the old material was "unprofessional" in that there were no syllabi, no course outlines, no reinforcement built in to the materials, few tests, and the material that did exist was photocopied rather than printed.

facility or at the customer's plant and must be usable in instructor-dependent or instructor-independent environments, and the widely divergent backgrounds of the students.

The program designers' analysis determined that, in order to make the course appropriate for delivery in a variety of training sites by CADAM or outside trainers, the course should depend on a workbook which would present the students with basic information and guide them through hands-on exercises. (The role of the instructors, then, would be to "facilitate" or assist the workbook-guided instruction, rather than to develop their own presentations of the required basics, as they had done in the past.) The program designers also determined, by means of an analysis of past students, that the material should be written at an eighth-grade reading level (except for engineering terms) to accommodate trainees of diverse abilities and backgrounds; that the reading should be kept to a minimum to allow for a maximum of hands-on practice and to keep student interest up; and that the course should not be "tied to machine-driven media" (such as audio-tape machines) so that each student could progress at his or her own rate.

Step 3. At this stage, the development team was organized, individual tasks and responsibilities were assigned, and time lines were drawn up. The project made use of both internal and external resources. CADAM trainers were consulted as subject matter experts, and an instructional designer from outside the firm was put on contract to write the curricular materials.

Development. The three steps of the development process are 1) identification of program objectives, 2) specification of instructional methods, and 3) construction of a prototype of the training program.

Step 1. The instructional design system used by CADAM designers identifies two types of program objectives: "terminal," or major, objectives, and "enabling," or sub-objectives that must be met to fill a major objective. At the end of this phase, the designer had created a "blueprint" of the training program -- a training outline, or "road map," that listed all the terminal and enabling objectives of the course, the

sequence of instruction, the time frame for each segment, the flow from one segment to another, and tests to be administered at various stages.

Step 2. During this phase, the designer works out the teaching and learning methods and the type of media to be used. While members of the CADAM program design department believe that the inductive learning method -- which allows the student to "discover" general principles by looking at or experimenting with specific cases -- is the most productive one, the time constraints of a customer training program required the use of the deductive method. Consequently, the primary learning method for the revised basic course presents students with general rules and procedures which can be applied to the majority of specific instances. At the same time, the designer attempted to include as much inductive learning as the four-day course would allow.

Since the CADAM Basic curriculum was designed to be taught as an independent self-study course or as an instructor-dependent course, the teaching methods specified for use by the trainers were geared toward helping the students make their own way through the reading sections of the workbook and assisting students when necessary during the hands-on exercises. The methodology used in the design of the workbook itself presents the students with an integrated series of exercises -- a hierarchical, or building-block, approach meant to insure that students master the basics of each step in the process before going on to the next step. Other methods specified include early exposure to the CAD terminal and the creation of a natural work environment and maximum opportunities for practical experience by gearing two-thirds of the instruction to hands-on practice on the terminal.

Aside from the student workbooks and other printed material, other media employed to support the training include audio-visual presentations and computer-aided instruction in the form of guided exercises on the computer graphics terminal.

Step 3. The third and final step in the development stage was the construction of the prototype of the training program. Following the blueprint design, the instructional designer wrote the first draft of the student workbook, using the building-block principle specified in step two and making sure that all of the basic operations of the CADAM system

were completely covered and were geared toward practical application. All of the lessons contained in the workbook present the student with the basic information, reinforce that information, and then test the students' knowledge before moving on to the next stage. Students learn these basics while moving through a guided instructional process in which they use all of the keys on the system's function keyboard (see p. 22 and Appendix B) to design an industrial robot.

Evaluation. This stage includes the following steps: 1) testing of the prototype, 2) analysis of the test results, and 3) implementation of the program, or, if the tests so indicate, redesign of some or all of the material.

Steps 1, 2, and 3. Field testing of the prototype was done by delivering it to a group of "typical students." There is a difficulty here in that the "typical" CADAM student can be a drafter, a designer, a manager, or an engineer. The tests, three in all, were monitored by the designer and a trainer, and student reactions to the course material were incorporated into subsequent curriculum drafts. During each test run, the instructor and the designer went over each page of the workbook with the students, requesting student comments on the clarity and usefulness of the material. The students themselves were then tested to determine whether or not the course was producing the required results.

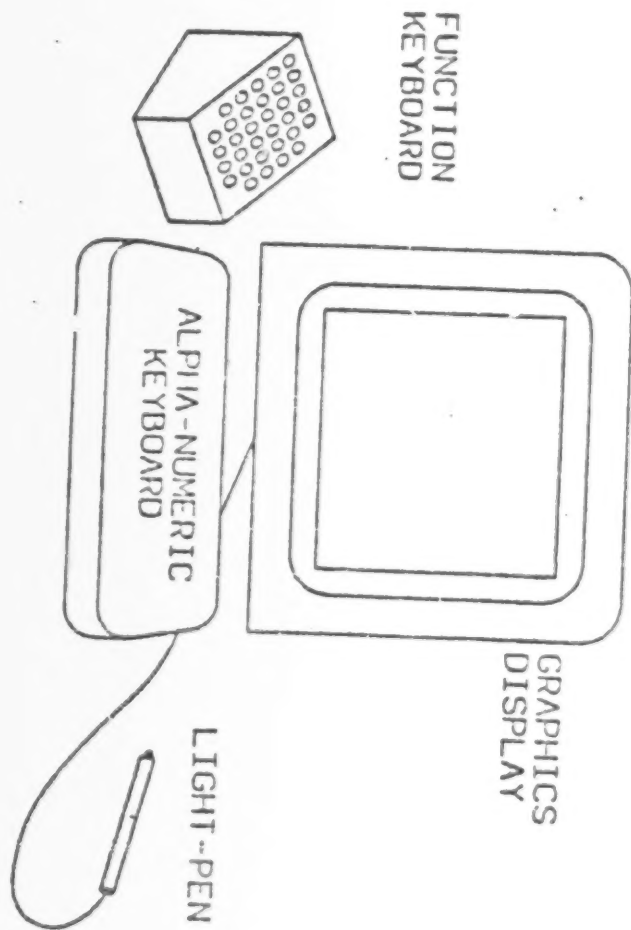
Analysis of the test deliveries showed that a major factor affecting student performance was reading ability and that the time required to complete the course ranged from 24 to 48 hours. The final version therefore stresses the importance of careful reading, and this emphasis is reinforced in the instructor's and manager's guides to the basic course. The production of the final printed version of the course material was completed in December 1982, and the revised course was ready for implementation in January, 1983.

While this design process is time consuming and expensive, the CADAM Training Division believes that training constructed on the instructional design model described above will, in the long run, result in the most productive and cost-effective training.

CADAM INC.

APPENDIX B

System
CADAM WORKSTATION



☐	☐	☐	☐	☐	☐	☐	☐
POINT	LINE	CIRCLE	SPLINE				
☐	☐	☐	☐	☐	☐	☐	☐
TYPE	RELIMIT	CORNER	OFFSET				
☐	☐	☐	☐	☐	☐	☐	☐
GROUP	SYMBOL	DETAIL	DIMENS	MISC			
☐	☐	☐	☐	☐	☐	☐	☐
R/C	PHAL	ANALZ	-MISC 2				
☐	☐	☐	☐	☐	☐	☐	☐
FILES	SHOW	AUX VIEW	ORIGIN	FRESH	INDICATE		
	☐	☐	☐	☐	☐	☐	☐
	WINDOW	TEST KEY	YES/NO				

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
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- C.5--MANUFACTURING ENGINEERING APPLICATIONS CENTER, WORCESTER, MA
- C.6--NEW ENGLAND PROGRAMMABLE AUTOMATION CUSTOMER TRAINING: COMPUTERVISION, GCA, AUTOMATIX
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- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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MAY 1984

COMPUTERIZED MANUFACTURING AUTOMATION:

Employment, Education,
and the Workplace

Volume II—Working Papers

Part C: Individual Education and Training Case
Studies

C.10— Henry Ford Community College: Electrical-
Electronic Technology Program, Automation/
Robotics Option

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

HENRY FORD COMMUNITY COLLEGE: ELECTRICAL-ELECTRONIC TECHNOLOGY
PROGRAM, AUTOMATION/ROBOTICS OPTION

Prepared for

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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

1983

Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

HENRY FORD COMMUNITY COLLEGE: ELECTRICAL-ELECTRONIC
TECHNOLOGY PROGRAM, AUTOMATION/ROBOTICS OPTION

General Background/Summary

Henry Ford Community College (HFCC) is a fully accredited 2-year college providing academic, technical-vocational, general, and continuing education programs for youth and adults. The college's main campus is located in Dearborn, Michigan, on 75 acres of land donated by the Ford Motor Company from property belonging to the former Henry Ford estate. Aside from the main campus, which is adjacent to the Dearborn campus of the University of Michigan, HFCC has two off-campus "centers": one, also in the city of Dearborn, houses one of the facilities of the Related Trade Instruction Division which offers training for people employed in skilled industrial occupations, primarily in apprenticeable skilled trades; and one in Dearborn Heights contains administrative offices.

The college has been offering instruction in technical areas since 1952, when the Michigan state legislature broadened the curricula of 2-year colleges to include technical fields.* Since that time, the college has grown steadily in course offerings and enrollment. Students may now choose from among 900 courses, and the 1982 enrollment is listed at 16,680. While the school district governing the college contains the cities of Dearborn and Dearborn Heights in the Southwest section of the Detroit Metropolitan area, over 77 percent of the student body resides outside of the district; the vast majority (12,100 out of 16,680) of the students attend on a part-time basis. Approximately 1,200 other students not included in the regular enrollment figures are union apprentices taking related trade instruction courses to fulfill the classroom/laboratory portions of their apprenticeship programs.

* The school's history goes back to 1938, with the founding of Fordson Junior College. In 1946, when the school district of the City of Dearborn was enlarged, Fordson became Dearborn Junior College. The college's name changed for the third time in 1952, when the Henry Ford Trade School closed and donated the money realized from a liquidation of its assets to the Dearborn Board of Education to expand technical and scientific education at the community college level. Some of these funds were used in 1955 to provide two new buildings for the newly named Henry Ford Community College of Dearborn. (Henry Ford Community College 1981-83 catalog)

Although official statistics on the employment status of students outside the related trade area were unavailable, instructors and administrators report that a large number of students are either presently employed and taking courses to improve existing skills, or were laid off from positions in auto and auto-related industries in 1981-82.

Apart from the apprenticeship program offered in the Related Trade Instruction Division, HFCC also offers occupational programs in such areas as applied arts, business and industry management, business, and industrial technology. The Industrial Technology Division, which prepares students for technician-level jobs, has degree programs in eight areas: architectural construction, automotive, drafting, machine tools, computer information systems, industrial materials, hospitality studies (i.e., hotel, restaurant, and institutional management), and electrical-electronics technology.

A number of currently or formerly employed students and recent high school graduates have enrolled in courses that make up part of the new "Automation/Robotics Option" of the Electrical-Electronics Technology Program.* Although this option was not formally offered until the fall semester of 1982, instructors in the Electrical-Electronics Technology Program have been teaching robotics and other programmable automation subjects for the past 10 years. Courses previously offered in the electronics program provided students with classroom instruction and laboratory work on programmable controllers, microprocessors, servo systems, and robot motions and controls. The Automation/Robotics Option combines the already existing courses with new and modified advanced courses specifically oriented toward the design and assembly of automation control systems. Students who complete the new option receive an associate degree in electrical-electronics technology and certification by Robotics International of the Society of Manufacturing Engineers (SME).

The decision to offer a concentration in robotics as an option and to design that option to include other forms of programmable automation reflects the college's view that students should not be "locked into" a degree-granting program in robotics. It is felt that a "robotics degree" would limit career

* Here again, few statistics could be obtained showing the precise number of students enrolling in this option. Figures that are available are discussed on p. 7.

opportunities, whereas a broader degree in electronics would give students the option to pursue a number of employment opportunities and career paths, including--but not limited to--robotics.

Electrical-Electronics Technology Program, Automation/Robotics Option

Planning and Development

Initial discussions leading to the development of the Automation/Robotics option began in 1981, when representatives of the Bendix Corporation visited the college to observe its Electronics Technology Program and to interview students for positions as robotics technicians. The 6 months of talks with Bendix resulted in the hiring of four students and coincided with an increase in requests by potential students and educational institutions for information on robotics courses and programs. Although both Bendix and Henry Ford representatives believed that the school's electronics technology graduates already had most of the skills required of robotics technicians, the growing public interest in robotics encouraged HFCC to begin developing plans for a formal robotics option within its already-structured electronics program.

In the spring of 1981, the school formed an ad-hoc advisory committee, made up of representatives from firms that produce robots, firms that produce automated machines that interface with robots, and Robotics International of the Society of Manufacturing Engineers. The committee reviewed the electronics technology curricula, toured classroom and laboratory facilities, and reviewed course requirements and sample problems completed by students as part of their coursework. While most of the committee members agreed that the existing program provided graduates with most of the needed skills, the committee as a whole did make three suggestions to strengthen the coursework and to focus it more directly on robotics and other areas of programmable automation. The recommendations were 1) increased emphasis on servo systems,* 2) the addition of a new course in computer-assisted circuit analysis, and 3) the addition of a segment in the program's industrial controls course focusing on actual machine motions.

* Systems that contain computer-controlled motors, transducers, sensors, and either circuits that control the electrical power flow or servovalves that control the flow of air or hydraulic fluid. (Robotics: Robot Technology and Function, L. F. Rothschild, Unterberg, Towbin.)

Acting on all of these suggestions, the college created new courses covering 1) computer-assisted circuit analysis, and 2) industrial automation and robotics. In addition, the existing courses in microprocessor systems and in circuit design, mechanical drives, and linkages were expanded.

Goals

The Automation/Robotics option is designed to help students meet specific occupational goals. Completing the option prepares graduates for technician-level jobs in assembly, field service, research and development, plant service, and sales in robotics and other forms of programmable automation. Students are informed that the union structure in the Big Three auto plants makes it unlikely that they would obtain maintenance and repair jobs in the plants unless they are already union journeymen or advanced apprentices having appropriate job classifications. HFCC students without proper union credentials are therefore directed toward jobs with programmable equipment producers and in smaller user firms. They would, however, be eligible for work under the direction of engineers in Big Three plants as salaried technicians responsible for designing controls or for testing logic systems. Students taking the Automation option are also prepared for a wide variety of electronics technician positions outside the field of programmable automation, including jobs in broadcasting, electronics firms, copy machine and office machine firms, and electrical power companies.

Administrative and Instructional Staff

The Electrical-Electronics Technology Program is one of eight programs administered by HFCC's Industrial Technology Division, which is comprised of two program administrators, eight full-time instructors, and eight part-time instructors. As a matter of policy, the college hires no instructor in its industrial technology and other technical divisions who does not have at least 2 years experience in industry. The director of the Industrial Technology Division has 20 years of industrial experience, primarily in automated machine manufacturing. The industrial experience of the instructors is varied and includes work in the auto industry and broadcasting (television transmission). All of the full-time instructors have Master of Science degrees, as do a number of the part-time faculty. Other part-time instructors

are employed in manufacturing or electronics and teach evening courses. Five full-time and eight part-time instructors teach courses required under the Electrical-Electronics Technology Program.

Facilities and Equipment

The Industrial Technology Division shares classrooms and laboratory space with the Related Instruction Division in the Patterson Technical Building, which occupies 62,329 square feet of space on the Dearborn main campus. Three classrooms and five laboratories are used by instructors and students in the Electrical-Electronics Technology Program. The present space in the Patterson Building is far from adequate to accommodate the steadily increasing numbers of students enrolling in Industrial Technology programs. Sections of the laboratory areas have been turned into classrooms; large classrooms and labs have been subdivided into smaller ones; and classes have been held in rooms belonging to academic divisions of the college. A proposal to construct a 77,000 square foot addition to the Patterson Building was approved by the college's administrative council and faculty senate. At present, however, college officials cannot project when the construction will begin.

Equipment holdings as of January 1983 include four non-servo, pick-and-place industrial robots (three of which are air-controlled and air-operated; one of which is air-operated and capable of being controlled by a programmable controller), 17 programmable controllers (12 state-of-the-art; 5 older models), digital logic trainers, a \$15,000 electronic test-and-measurement system, a \$20,000 servo-mechanical system, microprocessor trainers, a microprocessor lab system, and hydraulic trainers. These items are a small sample of the electrical, electronic, pneumatic, and hydraulic equipment in the college laboratories, which also contain oscilloscopes, multimeters and other measuring devices, transducers, probes, amplifiers, and a wide range of other equipment. Much of the training equipment has been fabricated, reconditioned, or rebuilt by the instructors, partly because funding problems preclude the purchase of commercial equipment in all instances, and partly because instructor-fabricated simulators and other equipment are more suitable than most commercial equipment for the instructional needs of the program.

Appendix A contains a listing of the pieces of equipment needed to implement the Automation/Robotics option at HFCC. The most crucial of these items is an

all-electric, servo robot which is small enough to fit into the school's present facilities. Because of the limited available space, the school requires small robots which, however, must be of industrial quality. According to the program director, the relatively inexpensive (\$2,500) miniature "teach robots" now on the market--while they may be appropriate for high school robotics programs and for programming courses in 4-year engineering colleges--are not adequate for the purposes of a 2-year technician program which focuses on troubleshooting, maintenance, repair, and interfacing robots with other machines. By the fall of 1984, the program staff plans to obtain or fabricate the machines and peripheral equipment required to construct a fully-automated miniature production line interfaced with small industrial robots. By the end of the fall 1983 semester, six miniature computer-controlled tooling machines will be in place as individual teaching stations and will become part of the automation line planned for the following year. These equipment plans are of a piece with the instructional focus of the program, which stresses robotics as it relates to other forms of automation and places major emphasis on control systems, the interface with peripheral equipment, and feedback systems.

Program Option Costs

Appendix A includes estimated costs for the major pieces of equipment recently obtained for use in the Automation/Robotics Option. Because a number of the Automation/Robotics courses overlap with other courses in the Electrical-Electronics Technology Program, and because much of the laboratory equipment was constructed by the instructors or has been in place for a number of years, it is not possible to provide a definitive breakout of other costs associated with the new program option. The estimated value of the existing equipment in the electronics, pneumatics, and hydraulics laboratories used by students taking the Automation option is \$425,000. Other cost items--including instructor and staff salaries, supplies, computer time-sharing costs and maintenance contract costs for special laboratory equipment (usually 1 percent of the purchase price, when)--were not available.

Student Selection

HFCC maintains an open-entry policy; there are, therefore, no selection procedures for students beginning basic coursework in any of its programs. However, to ensure that students already in the Electrical-Electronics Technology (EET) Program prior to the formal announcement of the Automation option would be given first preference to enroll in classes required to complete the option, these students were pre-enrolled before classes were opened to the general public. Since the courses designed specifically for students choosing the option are more difficult than parallel or alternative coursework in the EET Program, the necessity of completing prerequisite courses will result in a natural selection process. Instructors anticipate that students who successfully complete the Automation option will be a "cut above" the normal run of electronics students in math and physics and will have to complete more difficult coursework in microprocessors, circuit analyses, power systems, and mechanical interfaces.

Enrollment Trends

Precise statistical information on the number of students pursuing Automation/Robotics was unavailable because, while many students do declare their major programs of study on student information forms, they do not declare their choice of options within those programs. Furthermore, many students declare no major on the information forms, making it difficult to determine the exact number of students registered in the Electrical-Electronics Technology program. Out of the 6,000 students who did declare a major field or program of study in science and arts curricula, 600 declared themselves to be Electronics/Electricity majors. Approximately 16 percent of these students are receiving financial aid.

Instructors teaching courses in the EET Program report that, from a show of hands in the fall 1982 EET classes, one-quarter to one-third of the students currently enrolled in the program intend to pursue the Automation/Robotics option. Although the instructors could not make comparisons between those students declaring an interest in Automation/Robotics and those pursuing the basic EET course of studies, they did indicate some perceived trends characterizing EET students as a group and made some predictions about those

students most likely to succeed in the Automation option. In general, instructors and program administrators noted that more students in their late twenties and thirties were enrolling in the program; that the number of women enrolled has been increasing slowly but steadily; that especially in the last year, the number of students who have been laid off from auto and auto-related industries has increased; and that a large number of the enrollees are production workers seeking to upgrade their skills.

Many of the instructors think a significant proportion of those students now expressing their intention to pursue the Automation option have been influenced more by the current publicity surrounding robotics than by a reasoned assessment of their own capabilities and personal situations. Some students, they predict, will become discouraged when they discover the complexity of the course of study; some will not be able to develop the higher level of math, physics, and electronics skills required; and some laid-off workers may discover that their economic situation does not permit them to complete a 2-year course of study. With respect to placement, those who do succeed, instructors say, will not only need the higher level of skills the option will develop, but, to get jobs as customer service representatives for robot-producing firms or as technicians who maintain expensive computer automated equipment, they will have to display a high degree of confidence and responsibility to potential employers.

Curriculum

All students in the Electrical-Electronics Technology Program begin with courses in basic electricity and electronics and proceed to courses grouped into three sub-fields that parallel the three broad groupings of employment opportunities for electronics technicians: 1) computer circuitry and microprocessors, 2) circuit analysis and instrumentation, and 3) programmable controls and industrial automation. All EET students, therefore, are prepared for employment opportunities in a wide variety of industries by following course sequences that provide both flexibility and a solid foundation in a core discipline.

Students choosing the Automation/Robotics option complete courses in all three sequences of the core electronics program--computers, instrumentation, and controls--and also take additional coursework focused on computer-aided

automation and analysis and in-depth study of microprocessor systems. These courses emphasize the design and trouble-shooting of logic circuits found on automation equipment and how the various types of computer-automated equipment interface with each other and with peripheral equipment. In laboratory experiments, students progress from work on simulators to work on small industrial machines. The course sequence for the Automation/Robotics option students is as follows:*

First Semester

- + Basic Electricity
- + Introduction to Semiconductors and Electron Tubes
- Basic Hydraulics
- Political Science
- Technical Mathematics or Intermediate Algebra
- Health/Physical Education

Second Semester

- + Direct Current Circuits and Machines
- + Introduction to Pulse and Logic Circuitry
- * Computer Assisted Circuit Analysis
- Pneumatic Logic Circuits
- Technical Mathematics (continuation of first semester) or Trigonometry

Third Semester

- + Basic Electronic Circuitry Analysis
- + Digital Computer Principles
- + Alternating Current Circuits and Machines
- Physics
- English (Composition or Composition, Literature and Technical Communication)

Fourth Semester

- + Advanced Circuit Analysis and Instrumentation Systems
- * Automation Controls and Robotics
- * Microprocessor Systems
- * Power Systems and Mechanical Interfaces to Automation & Robots
- Industrial Electronic Systems
- English (continuation of third semester course)

* Courses marked with + are part of the core electronics program for all EET students. Courses marked * are expansions of regular EET courses or are newly designed for automation option students.

Appendix B contains a brief description of the core EET courses. The courses described below are those which have been expanded or created specifically for the Automation/Robotics option.

Computer Assisted Circuit Analysis. Students in this course use microcomputers with floppy-disk storage and color graphics to 1) design and create graphic displays of transistor amplifiers and D.C. power supplies and D.C. multi-voltage source resistor networks, 2) to generate programs capable of troubleshooting amplifier circuits, and 3) apply circuit analysis theorems. This new course, created on the recommendation of the Automation/Advisory Committee, is planned for the fall semester of 1983.

Automation Controls and Robotics is intended for advanced students who have a basic understanding of programmable controllers. Control specifications written by students for laboratory computer-aided machines and industrial robots will be used to implement controls for non-synchronous and synchronous operation of the machines. Specific topics will include techniques, terminology and documentation currently used in computer-aided manufacturing. This course is scheduled for the fall semester of 1983 or the spring of 1984 and will build on the "Alternating Current Circuits and Machines" course, which includes the study of programmable controllers and is a required course for all EET students.

Microprocessor Systems is based on a study of the 6800 Microprocessor and its family of support-integrated circuits. Students in this course study accumulator instructions, arithmetic and logic instructions, loops and timing loops, indexed addressing, use of stack, programming in assembly language, interfacing with external devices, interrupts, digital-to-analog and analog-to-digital conversion, serial data exchange and color graphics. The course is an expansion of the microprocessor course which has been taught as part of the Electronics program since 1979. Automation option students study some topics that are not covered in the regular microprocessor course--including serial data exchange, interpreters, and color graphics--and complete seven additional laboratory periods where they gain experience in interfacing robots and other programmable equipment to microprocessors.

Power Systems and Mechanical Interfaces to Automation and Robots is a revision of the advanced fluid power course taken by regular EET students. The course is designed to 1) acquaint students with servo feedback systems which continually monitor the speed and direction of mechanical devices that interface with fluid power systems, and 2) to explore the relationship between fluid power systems and mechanical devices driven by fluid power. This course is planned for the 1984 spring semester.

Instructional Methods

Classes are kept to a maximum of 24 students for lecture courses and 20 for laboratory courses. All of the technical courses in the Electronics program are laboratory courses with a minimum of 50 percent "hands-on" work. In some courses, this is formalized into a one-day lecture/one-day lab format; in other courses, 2 or 3 weeks of lectures are given before students proceed to the lecture-lab format.

While there are variations in teaching methods from instructor to instructor, there are significant similarities in approach indicative of a shared philosophy of vocational education delivery. All of the instructors place major emphasis on teaching the fundamentals of their particular areas of study and on practical laboratory experiments that, to the greatest extent possible, simulate actual industrial situations and problems.* In the context of the technical education and skills provided in the EET Program, "fundamentals" means not only theoretical principles, but also basic knowledge of electric and electronic systems and the pneumatic, hydraulic, and mechanical systems with which they interface. Students learn the fundamentals of the systems and interfaces in lectures, demonstrations, and--most importantly--laboratory experiments. Students in the microprocessor course, for example, write their own computer programs, draw up electronic schematics to interface with the external hardware, and do their own wiring. The theory behind the exercise is that, if the students can understand the microprocessor enough to make it perform given functions, they are better able to troubleshoot and repair it. Similar goals and methods are followed in the industrial controls courses. Students begin the industrial controls series by patching their own circuit

* This is an informal departmental policy. One of the qualities sought when hiring new instructors is adherence to the teaching philosophy outlined above.

designs into simulators which enable them to test the correctness of their designs. To study automated machine movements, students work on scaled-down machines that function exactly like the full-sized equipment found in computer-automated manufacturing facilities to become familiar with the relationship between logic control circuits and actual machine motions. By the fall of 1984, students will be able to work on a miniature automation line made up of six miniature tooling machines and four small industrial robots. The object of this series of courses is to teach students to examine machines, decide what type of control is required and what has to be controlled, determine the sequence of controls and write a program based on that sequence.

In the laboratory experiments, instructors make a point of providing the students with just enough preliminary information to enable them to set up experiments and to work out problems on their own. In the instrumentation classes, for example, students are given a rough outline of what the experiment should accomplish and copies of the instruction manual for the instrumentation equipment. In order to increase their sense of independence and responsibility for their own work, they are also given "service-call consulting forms" which they can use to get the instructor's assistance if they feel they are faced with an unsolvable problem--after one free call, students must "pay" for assistance in the form of a lowered grade for the experiment. This system, which has the added benefit of introducing students to industrial practices, has proved to be very successful and has encouraged students to attempt to find their own solutions to problems rather than rely on the instructor's assistance. In all of the laboratory experiments, the technique of allowing students to experience what, to them, are unanticipated problems helps them to gain a practical understanding of the workings of various systems. By specifically not warning students of the problems that can occur, instructors guide the students into situations which build their practical knowledge of the system and encourage their desire to understand it. As one instructor expressed it, students often have more impetus to explore and understand a machine or system when it is not working, than when it operates smoothly: "when something doesn't work, then they're ready to understand why--and that's the sort of thing you couldn't possibly put in a textbook."

This reliance on practical, hands-on learning situations is at the center of all of the instructors' teaching methodologies. The instructors in the EET program not only maintain their contacts with industry representatives in order to update the techniques and knowledge they use in classrooms and laboratories, but also work closely with one another to ensure a high degree of coordination between the content and methods of all the courses making up the program.

Internal Evaluation of Curriculum and Instructors

Newly hired instructors have a 1-year probationary period, during which time their courses and teaching methods are observed and evaluated by program and college administrators. While there are no formal evaluations by students, the director of the Industrial Technology Division maintains an open door policy to encourage students in the EET and other Industrial Technology programs to discuss academic and personal problems that cannot be resolved with the instructors. The director has found EET and other Industrial Technology students, whose average age is 29, quite ready to take advantage of the open door policy and extremely vocal about their opinions of the classes and the instructors. This policy has proved to be an effective, though informal, evaluation tool, and some of the instructors also request their students to fill out unofficial evaluation forms at the end of their courses.

Related Services: Counseling and Placement

While the instructors are responsible for academic counseling on such matters as curriculum content and course sequencing, the college also maintains a counseling and guidance staff whose specialists are responsible for counseling technical/vocational students. However, the availability of the instructors, their obvious interest in the students, and their knowledge of the students' abilities and needs encourage a large number of students to turn to the instructors for most of their counseling needs.

The college's placement staff includes an individual whose sole function is technical placement. The "placement officer" speaks to all graduating classes in the technical education divisions a few months before graduation and offers assistance with resumes and cover letters; posts current job offerings; and gives placement counseling to all interested students. Henry Ford alumni

registered with the placement office receive frequent bulletins listing job openings and special notices of "hot" job openings. A large number of the positions posted come from employers who have previously hired Henry For- graduates and from "cold calls" made by the placement officer (often as many as 25 a day) to local industries. The personal touch provided by the program instructors in academic and career counseling is also found in the area of placement counseling and services; examples of this are the placement officer's practice of driving students who have no means of transportation to job interviews and of holding workshops for graduates with placement problems.

Placement Statistics

Although HFCC operates an extremely active placement office, the feedback and reporting system has been far from adequate. Attempts by the technical placement officer to obtain information on the employment status from graduates registered with the office have been only partially successful. However, it is hoped that a new system whereby all employers who interview students from the placement office are sent follow-up forms requesting information on the interview's outcome will provide a more exact reporting instrument.

Of the 90 EET students who graduated in 1981, 32 responded to a placement survey conducted by the college. Approximately half of these students reported that they had obtained positions related to their course of study. Over 40 percent, according to placement office estimates, continued their education; approximately 5 percent entered the military; and the remainder either continued their education on a part-time basis or were unemployed.

Working from placement records more inclusive than the survey findings, the technical placement officer reports that at least 26 recent graduates found technician level jobs in the computer-aided manufacturing field.* The director of the Industrial Technology Division reports that a number of EET graduates have obtained computer-aided manufacturing jobs through channels other than the placement office and would therefore not be included in the

* This is an extremely conservative estimate based on only those students who found employment through the placement office and excluding those whose job descriptions were not reported with enough accuracy to make a precise determination.

official figures. In addition, the placement figures do not take into account the large proportion of EET students who were already employed full-time while attending classes to upgrade their skills and their positions. NOTE TO OTA: the placement office is compiling placement statistics for 1982, which will be more inclusive (and conclusive) than those for 1981. These will be sent to OTA in February 1983.

Relationships with Industry

While HFCC's relationship to industry is not unique, the school--in particular, its Industrial Technology and Related Trades Instruction Divisions--has traditional ties with the Ford Motor Company and other local industries. Located in a primarily industrial community, the college serves the needs of that community by maintaining an awareness of industrial needs through both formal and informal channels of communication with industrial representatives.* Formal communication is achieved through Industrial Advisory Committees and staff participation in technical societies; informal communication is a natural result of the college's requirement that all instructors in technical programs have previous industrial experience and of the instructors' commitment to keep abreast of new industrial developments and practices.

Industrial Advisory Committees

All of the degree-granting programs of the Industrial Technology Division have permanent advisory committees which meet formally at least once a year to review curricula and recommend modifications in light of current industrial needs and practices. Like other Industrial Technology programs, the EET Program has a standing advisory committee; however, to ensure that the Automation/Robotics option would meet the specific needs of students preparing to work with producers and users of computer-aided machinery, an ad-hoc committee was created to advise on the coursework and equipment required. The committee--made up of representatives from Unimation, Inc., Bendix Corporation, Cincinnati Milacron, Copperweld Robotics, F. Joseph Lamb and Company, Cross Company, and Robotics International of the Society of

* This characteristic is shared by a number of the 2-year colleges in the Detroit area.

Manufacturing Engineers--met once to advise on curriculum planning and equipment (see pp. 3-4) and will meet again in the fall of 1983 to provide comments on how the option is working in practice and to advise on future refinements.

While the formal meetings give advisory committee members an opportunity to discuss the program option as a full body and to reach a consensus on curriculum and equipment issues, most of the work of the committee is done informally by individual members working with HFCC program staff.

Representatives from Unimation and Copperweld, for example, worked with the instructor responsible for designing and delivering the advanced robotics and automation controls course; other committee members assisted in arranging for donations of equipment from their firms and encouraged other firms to contribute donated or wholesale equipment.

Industrial Needs Survey

Although the college did not conduct a formal industrial needs survey before instituting the Automation/Robotics option, it is now collaborating with two other colleges in the Detroit-Ann Arbor area (Macomb County Community College and Washtenaw Community College) in a study designed to aid other community colleges planning to develop robotics curricula. The study will determine the type of skills required of robotics technicians* and current planning and curricular activities of all 29 community colleges in Michigan.

Informal Industrial Relationships

The close informal contact between the instructors and representatives of industry not only helps keep the curricula up-to-date but also results in donations of parts or used equipment which the instructors disassemble and use to fabricate specially designed equipment suited for laboratory use. The instructors also make use of the time between semesters to visit local industries to view new developments in operation, and most are members of technical societies, whose meetings provide a further avenue of communication with professionals in industry. The program director spends a significant proportion of his time talking to industrial representatives to make sure that

* An outside consultant was hired to survey robot users and producers to aid in pinpointing those skills.

all of the programs in the Industrial Technology division keep pace with current practices and to pinpoint opportunities to obtain donated or favorably priced equipment. Another significant point of contact with local industry is made through the program's part time instructors, many of whom work in industry and teach classes at night.

Internships, Co-operative Work-Study, and Other Programs with Industry

Because of a lack of funds to cover the staff required to administer them, the Electrical/Electronic Technology Program does not operate formal co-op programs.* It does, however, have informal co-operative work-study agreements with Eastman Kodak and F. Joseph Lamb and Company. Students participating in these programs must have completed at least half of their core subjects and work during the day while attending classes at night. Although the students in the Kodak program do not work in the field of robotics, some of the students in the F. Joseph Lamb program do work with programmable controls. Lamb representatives, who hire co-op students from other local colleges as well as HFCC students, give high marks to the Henry Ford students and praise the practical orientation of the school's curriculum and the amount of hands-on training the students bring into the workplace. The EET staff is currently working on a possible cooperative arrangement with a local robot producer, but, as of this writing, no definite arrangements have been made.

In the past, the college has held seminars for industrial employees. One, held in 1980, consisted of workshops for Unimation service personnel on the theory and operation of microprocessors and programmable controllers. Since, however, the Industrial Technology Division is rapidly outgrowing its existing facilities, its present capacity to host industrial workshops and seminars is extremely limited. HFCC faculty and administration hope that the proposed

* The EET staff helped to develop a cooperative work-study program for the four students hired as robotics technicians by the Bendix Corporation (see p. 3). HFCC does not, however, participate formally in this program, which is a cooperative endeavor between Bendix and Wayne State University whereby Bendix trains the participants in its production requirements and practices and pays their tuition in Wayne State's engineering technician program. The program is designed so that the Henry Ford graduates can stop training at any stage and enter the position most suited to their skills at that time. Unfortunately, although Bendix reported that all four of the students were performing well, two of them had to be let go during a recent series of layoffs.

extension of the technical building will provide the needed space to conduct such activities in the future.

Relationships with Technical Societies

The program director and some of the instructors are active in the Fluid Power Society and the director is a member of the Society for Manufacturing Engineers (SME). Robotics International of SME provides certification for all students who successfully complete the coursework for the Automation/Robotics option.

Relationships with Labor Unions

While Henry Ford Community College maintains close ties with the United Auto Workers and other unions through its Related Trade Instruction Division, the unions do not participate formally in the advisory committees serving the Industrial Technology Division's programs,* which are designed primarily for students preparing for technician-level positions as salaried employees in union shops or for salaried or hourly jobs in non-union shops. However, the director of the Industrial Technology Division was once active in the UAW and has close relationships with UAW representatives. This provides an informal channel of communication through which the union is kept abreast of new HFCC developments, such as the Automation/Robotics option.

The college does work closely with Joint Apprenticeship Committees in the apprenticeship programs operated by the Related Trade Instruction Division. The college, in fact, was chosen by Ford and the UAW as the site of the

* The types of manufacturing trade programs at HFCC parallel the two types of local employment opportunities in manufacturing: 1) the Related Trade Instruction Division serves union apprentices, and 2) the Industrial Technology Division serves students preparing for non-union technician jobs. However, a number of journeymen have enrolled in Industrial Technology programs to increase their manufacturing skills and to study such topics as robotics.

Targeted Vocational Retraining (TVR) pilot projects provided for under the 1982 collective bargaining agreement.*

Although the initial TVR pilot projects do not train workers in computer-aided manufacturing skills, the Related Trades Division--which offers regular related trades programs and over 200 special courses of study for the employees of specific companies--provides a number of courses in industrial controls. The majority of these courses are taught in the Industrial Electrician Program, which has included a course in programmable controllers since 1973. In 1980, the college received Federal funds to undertake a curriculum revitalization project in the industrial electrician coursework. The result is a performance-based series of courses, one-third of which are in the area of electronic controls systems, including microprocessors and programmable controllers. A second revitalization project, now in the proposal stage, would revise the fluid power curriculum to meet present and future needs, and would include the addition of robotics courses focused on mechanisms, automated lubricating systems, or electro-mechanics.

An example of a special program operated for an individual company is the updating program for journeymen industrial electricians employed by Cadillac Motor Car Company. The two-semester program began in the fall of 1982 and trains 24 journeymen in the fundamentals of electronics, microprocessors, and programmable controllers. The director of the Related Trades Instruction

* The TVR projects, part of the Ford-UAW Employee Development and Training Program (EDTP), are intensive retraining programs for Ford-UAW employees who have been on indefinite layoff for 6 months or more, who have at least 5 years of company seniority, and who have recall rights under the 1982 collective bargaining agreement. The two pilot projects conducted at HFCC trained laid-off workers to be certified accelerated-pipe-and-pressure-vessel welders and tool-and-die drafters. The latter program, funded by the Michigan Employment Security Commission, also included workers laid off from other companies. Both of these occupations were accepted by the Ford-UAW National Training Center staff as occupations with definite placement prospects (a provision required under the bargaining agreement). Programs focusing on the area of reprogrammable automation were not developed for the pilot run because 1) HFCC had difficulties in obtaining proper space and equipment (see pp. 6-7), and 2) information gathered in labor market surveys did not indicate that definite employment prospects would exist in this skill area in the near future. More surveys are being conducted, however, and HFCC is considering a future proposal to the National Training Center of programs to retrain laid-off electricians in the skills required to maintain and troubleshoot programmable controllers and microprocessors.

Division plans to propose a project based on the Cadillac program to the Ford-UAW National Training Center as a future TVR project.

Apprentices who complete the required 576 hours of related instruction (which translates into 19 two-credit-hour courses at HFCC) and the appropriate amount of on-the-job training receive certification of journeyman status by the Federal Bureau of Apprenticeship Training. Students who have completed the 38 credits required under the apprenticeship training system may then take a special option to complete the remaining 24 credits required for an associate of science degree or may transfer to the Industrial Technology division with some loss of credits.

Evaluation of Present and Future Capacity

The strengths of the training in programmable automation provided at Henry Ford Community College are 1) the dedication, experience, and skill of the instructors; 2) the strong emphasis on providing a solid foundation of basic skills and knowledge coupled with an equally strong emphasis on practical laboratory experience; and 3) the flexibility of the program option, which provides students with the skills to obtain jobs in computer-aided manufacturing as well as in other areas of industrial electronics. Its major weaknesses derive primarily from lack of adequate funding: the space available for classrooms and laboratories is inadequate, and the school has difficulty in obtaining all of the up-to-date equipment required for the Automation/Robotics option.

Instructors

The comments of "Automation/Robotics" students interviewed for this study attest to the skill and dedication of the instructors.* All of those interviewed gave the instructors high marks in classroom instruction, teaching methods, knowledge of course material, and design of laboratory experiments. Two comments by two different students bear repeating. One said: "The thing I think is really great about these teachers is that they'll tell you just enough—and you start pulling your hair out and scratching your head, but all of a sudden--boom!--you're learning." The other, confirming the comment of the first, said, "You don't do things mechanically here. You have to think for yourself." The students also commented that the instructors were always available before and after classes and at the end of the day for assistance with classroom and laboratory work and for counseling on academic and other problems. Aside from spending a great deal of time providing extra assistance to students, the instructors also donate time to such activities as fabricating special laboratory equipment, working with industrial contacts to obtain new or used equipment and to keep current on new industrial practices, and visiting industrial sites between semesters. Some have also made their own videotapes and tape-slide presentations of laboratory experiments.

The instructors themselves pointed out the importance of coordination among the teachers in a program like Electronics Technology, which--as taught at HFCC--includes interdisciplinary studies in mechanics, hydraulics, and pneumatics and covers a wide spectrum of electronics skills. The instructors believe that it is their responsibility not only to shape their own courses in a coherent manner but to work with the other instructors to make sure that the entire program has continuity. This concern for continuity also exists on the administrative level, where faculty hiring practices take into account not

* Five students--four men and one woman--were chosen at random from among those students taking the Automation/Robotics option. Four had previous industrial experience--two in the auto industry, one in construction, and one in industrial sewing. Few had attended other colleges but said that they chose HFCC on the strength of its reputation and the quality of its instructors. One, who had attended four other colleges in the area, entered the EET program because, in his words, "The teachers here are some of the best I've ever had, and I've been the route." Three students were interviewed as a group; two were interviewed individually.

only knowledge, skills and background, but the ability to work as part of a team.

Curriculum and Teaching Methods: Program or Option?

Because instructors in the EET program have been teaching programmable automation for the last 10 years—including courses on programmable controllers, microprocessors, and a section on robotics in fluid power courses—the director and staff of the program believed that only a minor restructuring and some additional courses were needed for the new automation option. Also because of the long-time focus on both "hard" and programmable automation, the instructors' teaching methods have not changed significantly with the introduction of the option. Although the content of the courses has changed as new developments have occurred in the field of industrial electronics, the teaching methods, the emphasis on the fundamentals, and the insistence on hands-on experience in laboratory experiments has remained essentially the same.

The majority of the industrial representatives on the Automation/Robotics Advisory Committee—a number of whom had hired graduates of the EET program—stated that the program was meeting the most critical industrial hiring need by producing graduates with solid basic knowledge and practical skills. Those who had hired HECC graduates confirmed that they did have the required basics and a commendable amount of practical know-how.

While the Advisory Committee members were in agreement on the critical importance of basics and hands-on experience, there was some disagreement on how programmable automation coursework—specifically robotics coursework—should be focused and on the desired amount of specificity in the training on the variety of computer-aided systems used in industry. Henry Ford's program trains students in the basics of one system—one microprocessor system, for example, and one commercial programmable controller system—on the theory that, if they know the basics of one commercial system, they can readily learn the specifics of other systems with a small amount of on-the-job training. Because of the limited time available in a 2-year course of study—which must include the basics of electricity, electronics, mechanics, pneumatics, and hydraulics as well as the basics of the operation of microprocessors, programmable controllers, and robots—the program staff believes that it is

industry's responsibility to train in the specifics of the particular systems in use in individual firms, while it is the college's responsibility to provide the foundation on which those specifics can be built. Although the majority of the representatives on the advisory committee were in full agreement with this point of view, some thought that students should have more exposure to the variety of commercial systems in use.

The other difference of opinion among the committee members--some of whom also served on advisory committees for other local colleges--arose in reference to the focus of the automation coursework. While the majority of the representatives approved of HFCC's decision to offer automation coursework as an option and not as a highly focused degree-granting program in robotics, two committee members preferred the approach of another local school that is preparing to offer a 3-year, degree-granting program in robotics. On the other hand, the students interviewed were unanimous in preferring the option over a degree-granting program, which, they felt, would limit their employment opportunities.

While it should, of course, be noted that students preferring a degree program over an option might be likely to enroll in a college that offers a course of study leading to a robotics or integrated manufacturing degree, it should also be stated that the factors influencing the choice of schools of those students interviewed were the general reputation of HFCC's Industrial Technology Division and the reported excellence of its instructors, not the focus or structure of the automation option.

The lack of consensus among the Advisory Committee members on the question of the structure or focus of the Automation/Robotics coursework at HFCC brings up a number of more general concerns. Since integrated manufacturing curricula is relatively new, few, if any, tested models exist on the 2-year college level, and each college must decide how best to serve the needs of its community and its students. In the Detroit area, numerous approaches are being planned or attempted by a variety of colleges, but the programs themselves have not been in operation long enough to provide the basis for a true evaluation of their relative merits. In addition, many colleges may, like Henry Ford, find that serving the needs of both the students and industrial employers in their localities entails balancing one set of needs against the other and arriving at a reasonable compromise. While employers--

especially those who are producers or heavy users of programmable equipment--need highly skilled and appropriately trained workers, students--whether they are underemployed, laid-off, or just beginning to prepare for future careers--need jobs as well as skills. Within the next 2 to 3 years, a large number of students are expected to graduate with degrees or certificates in robotics and/or integrated manufacturing. How many of these students will obtain jobs in the field, what kind of training is most successful, and which of these students have the best general employment prospects remain to be seen.

Facilities and Equipment

All of those interviewed--students, instructors, administrators, and industrial representatives--agreed that the college's facilities and equipment were in need of improvement. HFCC is in a particularly difficult financial situation because it is one of the few community colleges in the state that must rely on millage from city taxes for some of its revenues, while the majority of the state's community colleges receive millages from larger county tax bases.* HFCC does, however, have sufficient local revenues to enable it to make use of the matching funds arrangement offered by the state, [i.e., the institution's funds for equipment and facility construction are matched with Federal Vocational Education funds.] Via this agreement, the college has \$276,000 to use over 3 years (beginning in 1982) to purchase equipment and renovate facilities.

The proposed addition to the technical building should ease the space problem, and the EET Program director is actively working on obtaining the priority equipment item for the automation option--an all-electric robot which is state-of-the-art yet small enough to fit into the current available space. The students interviewed, while they did think that the lack of some items of up-to-date equipment was a problem, thought that the benefits of the program--the structure of the courses and labs and the abilities of the instructors--far outweighed its inadequacies in equipment and facilities.

* HFCC receives 47 percent of its revenues from the state, 17 percent from city taxes, 9 percent from federal funds, and the remainder from student tuition and fees.

It should also be noted that the school does have adequate numbers of programmable controllers and well outfitted electronics and fluid power labs (the latter containing four pneumatic industrial robots), and that these laboratories contain a large amount of instructor-fabricated equipment which is specifically designed for instructional purposes. Much of this equipment cannot be bought commercially and, according to the HFCC staff, is capable of demonstrating principles and practices which cannot be demonstrated on commercial equipment.

The college does not make a practice of asking local industries to provide factory space and production equipment for hands-on training of HFCC students for two major reasons: first, industries are often reluctant to allow students to work on expensive equipment; also, since many of HFCC's students work as well as attend school, their schedules allow little flexibility in arranging in-plant training. According to Henry Ford's Industrial Technology Division director, arrangements with industry such as that described above are easier to establish in newly developing industrial areas which need new workforces than in well established areas like Detroit, where trained workers are being laid off or furloughed.

Future Capacity

HFCC's traditional ties to industry and its awareness of ongoing industrial developments contribute to both its present and future capacity to provide education and training in computer-aided manufacturing. Having kept pace with industrial developments, the EET faculty was not caught short by the "robotics boom," but rather was able to develop and implement an "Automation/Robotics" curriculum by making relatively minor modifications and additions to the school's existing Electronics program. This awareness of industrial needs suggests that the school's future capacity to anticipate new directions in the field of industrial automation and to implement new courses as needed will be high.

The college's decision to offer Automation/Robotics coursework as an option, rather than as a degree program, enabled it to move rapidly to implement the new coursework, since the school did not have to wait for state certification (which is required for new programs but not for options). The school's choice of an option rather than a discrete program is also indicative of its moderate

approach to public and industrial demands for education that responds to current needs. By responding with a flexible option rather than with a highly focused program, college representatives believe that they are meeting present needs while retaining the flexibility to adapt to future needs of the students in a locality with an uncertain economic future. Although one-third of the USA's robot producing firms are located in Michigan and long-term economic forecasts predict growth in robotics, the students interviewed were more concerned with the present economic climate and the massive layoffs affecting area residents than with forecasts of potential growth. These students felt that a general degree in electronics technology with a specialization in robotics would make them more employable than a highly focused degree because it would allow them more flexibility in the types of jobs they could seek.

The college has recently increased its efforts to obtain donations from industry to help solve its equipment problem. Once the new addition to the technical building is completed, and if industrial funds are forthcoming, HFCC could be equipped to provide substantial assistance to the community by retraining many of its laid-off workers. Along with the Targeted Vocational Retraining projects mentioned on pp.18-20, the Ford-UAW retraining agreement includes the provision of funds to employed or laid-off workers to cover tuition for approved educational courses in accredited institutions. A number of Ford-UAW employees are currently enrolled in the Automation/Robotics option and are receiving tuition reimbursement under the vocational retraining assistance plan. The new facilities and more equipment would enable the EET program to enroll more workers in need of retraining. Given the traditional relationship between Ford and HFCC (which trains approximately 75 percent of Ford's apprentices) it is not unlikely that a number of Ford workers would avail themselves of the opportunity to take advantage of the integrated manufacturing coursework available.

HFCC representatives believe that the Electrical-Electronics Program could accommodate such growth without diluting its greatest strength--instructors who work well together and provide the students with a large amount of curricular and extra-curricular assistance. The Industrial Technology Division has a long list of qualified applicants for teaching positions and has developed an "in-house grooming system" to help new instructors--who are selected on the basis of commitment to teaching as well as skills--to develop

their own teaching techniques and to work as a part of a coordinated department.

In summary, Henry Ford Community College is an example of a school with the foresight to anticipate industrial trends and the faculty expertise to design and implement appropriate technician-level coursework. Like many colleges across the country, however, it is hampered by limited funding and limited space. Dedicated instructors, who donate the time required to build equipment which the school could not otherwise afford, lessen the problem but cannot possibly solve it. The long-range solution sought by HFCC—the acquisition of state-of-the-art equipment and adequate funds to maintain that equipment and expand existing facilities—requires external assistance, through industrial donations and/or State or Federal grants. While the college's Industrial Technology Division actively pursues industrial assistance and just as actively seeks to shape its program to meet industrial needs, Division representatives are reluctant to adopt a number of innovative approaches taken by colleges in other areas of the country.

One such solution, a program providing students with access to industrial facilities, would require both a high level of industrial cooperation and careful planning to enable working students to attend labs at odd hours. Programs of this sort have been instituted in other localities,* but their potential for long-term success is thrown into question by the following factors: 1) businesses eager to accommodate schools by allowing students to train on their equipment in return for the opportunity to hire the best of those students often become less willing to enter into such arrangements when their employment needs are met, and they are less able to make such arrangements when they must institute hiring freezes or layoffs; 2) in industries where production equipment is in use during two or sometimes three shifts, it is often difficult, if not impossible, to free that equipment for non-production use. This type of industrial alliance, therefore, may be more appropriate as an interim solution for colleges attempting to build new programs than for colleges like Henry Ford which are attempting to sustain ongoing programs.

* See Case Study #8, Glendale Community College CAD/CAM Operator Program.

Another solution, which has more potential for longevity than the use of industrial facilities, is the consortium approach, which can take two forms: 1) a consortium of schools in which the equipment required to teach specific curricula is allotted to specific schools, or 2) a centrally located laboratory facility equipped by a consortium of industries, perhaps aided by Federal funds, and containing the pooled resources of local colleges. The first variation on the consortium approach has been instituted in South Carolina and is in the planning stage in Oregon. While the director of HFCC's Industrial Technology Division agrees that such an approach could help to solve funding and equipment problems, he points out some practical drawbacks that are specific to the Detroit area, where a number of colleges are now either offering or developing robotics curricula: first, it would be difficult to determine which schools would be deprived of already operating programs, and in addition, each school serves local needs as well as the needs of the wider Detroit area, making it extremely difficult to divide curriculum areas among the many schools. The second option--participating with other colleges to gain industry support for a centralized laboratory facility--is perhaps more realistic in the Detroit area but would entail enormous logistical problems for students and faculty alike. Furthermore, other colleges in the area which have more funds, better facilities, and more equipment would have even less incentive than HFCC to participate.

The overall picture in the Detroit area is one of community colleges competing with each other and sometimes with 4-year colleges, universities, proprietary schools, and high schools for industrial equipment and materials and for the time of industrial representatives, many of whom sit on more than one school's industrial advisory committee. Although there are numerous instances of these educational institutions working together to assist each other and the educational community in general,* the spirit of competition seems to overcome the spirit of cooperation in the area of funding and equipment needs. Considering the problems detailed above, the reluctance of HFCC to participate in a consortium endeavor that could entail the loss of established programs that are well received by students and industry alike is understandable--as is the reluctance to devote the time and effort required to gain support for a

* The study conducted by Henry Ford, Macomb, and Washtenaw mentioned on p. 16 is but one example of cooperative action.

central laboratory facility that would impose travel and scheduling hardships on faculty and students and could lessen the close-knit and supportive atmosphere now existing at the college. Other cooperative solutions entailing fewer difficulties--such as 1) mobile laboratories containing the most expensive and sophisticated equipment for advanced labwork while existing labs for more basic electronics, pneumatics, and hydraulics coursework remain in place in separate schools, or 2) mutual access to college laboratories which may contain different makes and types of robots and computer-aided equipment for selected advanced courses--are yet to be explored in the Detroit area. These types of approaches would leave already-developed curricula and individual instructional methodologies essentially intact, but they involve a great deal of give-and-take among schools and some sacrifice of separate resources and individuality of approach.

A number of colleges in the Detroit area have succeeded in implementing programs, attracting even more students than can be served, and--to greater or lesser degrees--obtaining equipment. They do not, at present, have the incentive to enter into cooperative arrangements that would dilute existing individual gains, but in a field like computer-aided manufacturing, in which equipment is expensive to obtain, maintain, and update, the independent use of separate resources may limit the capacity of individual educational institutions to meet future training needs.

APPENDIX A
Major Cost Items Purchased to Implement the Robotics Option

	<u>Retail</u>	<u>Discounted</u>
1. Three Allen Bradley PLC 2/15 and two PLC 2/30 programmable controllers.	\$46,667.00	\$42,000.00
2. Ten Allen Bradley Push Button Stations.	2,444.00	2,200.00
3. Allen Bradley proximity switches for power panels.	7,444.00	6,700.00
4. Reconstruction and updating of two autoplacement point-to-point robots for electrical control.	4,000.00	4,000.00
5. Fabrication of machines for laboratory automation system. This activity entails the use of existing HFCC machines.	10,000.00	10,000.00
6. Pneumatic valves for fabrication of power panels to provide ten laboratory work stations.	7,101.00	3,905.00
7. Cylinders for fabrication of power panels to provide ten laboratory work stations.	12,000.00	4,600.00
8. Allen Bradley cassette recorder to provide storage capability for programmable controller programs.	3,333.00	3,000.00
9. Two miniature drill machines for automation assignments.	8,000.00	8,000.00
10. Two DC instructional servos.	6,640.00	6,640.00
11. Articulated servo controlled continuous path robot.	40,000.00	40,000.00
12. Two pick-and-place pneumatic robots.	33,600.00	28,560.00
13. Four pneumatic slides for transportation of point-to-point robots.	8,400.00	6,300.00
TOTALS	\$189,629.00	\$165,905.00

APPENDIX B

Electricity/Electronics Technology Course

Basic Electricity -- a beginning lecture course covering the fundamentals of electricity. Topics include electron theory, Ohm's Law, circuits, magnetism, inductance, capacitance, alternating current circuits, and resonance.

Introduction to Semiconductors and Electron Tubes -- an introductory course to common electronic devices. Discussion and laboratory work focus on transistors, vacuum tubes, and other semi-conductor devices.

Direct Current Circuits and Machines -- an intermediate level course providing coverage of DC circuitry with emphasis on circuit theorems, power, electrical energy, magnetism, and measuring instruments. Also included is an introduction to DC machines and control devices.

Introduction to Pulse and Logic Circuitry -- an introductory computer course covering the electronic pulse circuitry used in computers, radar, guided missiles, television, and test equipment. Units of study include pulse amplifiers, gates, wave shaping, oscillators, multivibrators, number systems, and Boolean algebra.

Basic Electronic Circuitry Analysis -- an intermediate level course covering fundamental circuits and their characteristics and designed to provide an understanding of power sources and amplifier systems. Laboratory work consists of experiments in rectification, filtering, regulation, amplification, and coupling.

Digital Computer Principles -- an advanced computer course covering logic and language, circuitry, and computer operation.

Alternating Current Circuits and Machines -- an advanced course covering AC circuitry, alternators transformers, polyphase systems, power distribution, AC machines, relays, and programmable controllers.

Advanced Circuit Analysis and Instrumentation Systems -- a continuation of "Electronic Circuitry and Analysis" that includes discussion and application of transducers, feedback, oscillators, integrated circuits, and special semiconductor devices. Students study principles and applications of instrumentation systems, including accelerometers, strain gauges, load cells, and magnetic pick-ups.

Industrial Electronic Systems -- an advanced course covering the design of basic electronic circuits common to many industrial electronic systems, such as electronic motor controls, resistance welders, and servo systems.

Introduction to Microprocessors -- an advanced course on the 6800 microprocessor for students who do not choose the Automation/Robotics option. Topics covered include most of those described under the "Microprocessor Systems" course (described on p. 10); topics excluded from this non-option course are serial data exchange, color graphics and robot applications.

Students taking the Automation/Robotics option are required to take a course in basic hydraulics and an introductory course in pneumatic logic circuits. These courses, which have been offered for the past 10 years as electives in the EET program, are also open to students who do not choose the Automation option.

COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

VOLUME II - WORKING PAPERS

Part C - Individual Education and Training Case Studies

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- C.2--GENERAL MOTORS TRUCK AND BUS "S" TRUCK PLANT, PONTIAC, MI: "NEW TECHNOLOGY TRAINING"
- C.3--BRIGHAM YOUNG UNIVERSITY: THE EDUCATION OF TECHNOLOGISTS
- C.4--CAD/CAM OPERATOR TRAINING PROGRAM, GLENDALE, CALIFORNIA
- C.5--MANUFACTURING ENGINEERING APPLICATIONS CENTER, WORCESTER, MA
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- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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COMPUTERIZED MANUFACTURING AUTOMATION:

Employment, Education,
and the Workplace

Volume II—Working Papers

Part C: Individual Education and Training Case
Studies

C.11— Westinghouse Defense and Electronics
Systems Center, Baltimore, MD

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:

WESTINGHOUSE DEFENSE AND ELECTRONICS SYSTEMS CENTER, BALTIMORE, MD

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

WESTINGHOUSE DEFENSE AND ELECTRONICS SYSTEMS CENTER
BALTIMORE, MARYLAND

TRAINING FOR COMPUTER-AIDED TECHNOLOGY

SUMMARY

The Westinghouse Electric Corporation Defense and Electronics Systems Center manufactures surface and airborne electronic guidance systems, primarily for the Department of Defense (DOD). Committed to the introduction of programmable automation with minimum disruption of the workforce -- if possible, with no layoffs -- the Defense Center began in 1980 to formally address 1) the hourly production workers' need for training in the use of new equipment, and 2) their need for retraining when dislocation is unavoidable. The Defense Center has had automated "technology pockets" for a number of years. Now, however, the computer-aided management information system networks the Center's CAD, CAM, Computer-Aided Inspection (CAI), and Computer-Aided Testing (CAT) systems. Since 1980, a number of new factory automation systems--including an automated materials handling system, robot systems, and a number of new CNC and DNC* installations--have been introduced to the plant floor. The computer-aided management system--which is taking the Defense Center in the direction of the "paperless factory"--and the new plant-floor automation systems created the need for training strategies that could quickly address the continually changing needs of shopfloor workers and that would be applicable to both mass-training (when hundreds of workers would be affected) and small-group training. Eventually, training for new technology introduced to the plant floor will be based on a single approach, designed to be flexible enough to be adapted to the varying requirements of all affected workers. In the pilot program to train 250 workers for a newly opened computerized materials acquisition center, the new approach modified the traditional roles of engineers, supervisors, and shopfloor workers. The approach was to take the technical documentation for the system (written by Westinghouse engineers,

* Computer Numerical Control and Direct Numerical Control machines.

who developed their own applications software and peripheral hardware for vendor-supplied automation systems) and to use that as a basis for users' manuals and lesson plans for the shopfloor workers who operate the systems. In the materials acquisition program, supervisors provided input for the training manuals and lesson plans. The new method of training delivery turned the development engineers into "master trainers" and the first-line supervisors into part-time trainers of their own employees. In essence, the training process followed the path of the technology itself from applications lab to plant floor operation and employed as trainers those who developed the system (the engineers) and those who manage it (the supervisors).

Another programmable automation training program at the Defense Center provided a series of robot operations courses (both vendor-delivered and company-delivered) to all eight welders in the sheet-metal fabrication area's welding department. Two months before the training began, the welders attended an orientation-to-robotics session at the research laboratory (the Manufacturing Systems and Technology Center) where applications for the welding robots were being developed. As in the Materials Acquisition Center program, the engineers who developed the applications delivered the training. However, because the robot operations program was delivered to a small group of trainees, the engineers--together with the vendor trainer and a full-time training manager attached to the operations area--trained the operators directly. The training took place while the engineers were completing the applications work on the robot to give the welders the opportunity to advise the development engineers on shopfloor welding requirements. A number of the welders' suggestions were incorporated into the system's software.

This study explores the materials acquisition program and the welding robot program as examples of mass-training and small-group training in programmable automation at the Defense Center. It also discusses the new training strategy, as exemplified by the materials acquisition program. Section I describes the Defense Center's production and research facilities. Section II gives a training overview, and discusses the organization of the Defense Center's training resources and its philosophy of training. Section III describes in detail the two models (the mass training model and the small-

group model) developed to train hourly workers for computer-aided technology. Section IV evaluates the Defense Center's present and future training capacity.

I. BACKGROUND

Company Characteristics.

Employing over 15,000 people, the Defense Center is part of the Westinghouse Energy and Advanced Technology Group, one of three Westinghouse companies. The main production facility is located in two buildings adjacent to the Baltimore-Washington International Airport, just south of Baltimore, Maryland. The West Building is devoted to the manufacture of heavy-metal surface-radar systems like dish antennas and radar towers, while the East Building produces radar and guidance systems of lighter, thinner metal for airborne use. Hourly workers in the East Building have already been trained to operate the first robot introduced in the Defense Center, and robotics technology will soon be applied to the manufacture of surface systems in the West Building.

Two miles away is a newly opened Materials Acquisition Center, where 250 workers have been trained to use a new centralized information-processing system. In nearby Baltimore a satellite plant manufactures cables and harnesses for use in electronic guidance systems.*

Aside from DOD, the Defense Center also works under contract to the Federal Aviation Administration, the North Atlantic Treaty Organization, and the National Aeronautics and Space Administration, as well as to foreign customers like Egypt, Saudi Arabia, and Japan. Since DOD is the chief customer, most products are manufactured to U.S. military specifications.

* A second satellite plant, which will completely automate electronics assembly, recently opened in College Station, Texas (180 miles south of Dallas).

Research and Development Facilities.

Fifteen miles west of the Defense Center, in Columbia, MD, the Manufacturing Systems and Technology Center develops state-of-the-art information processing, robotics, and automated manufacturing systems. The systems developed at the Technology Center primarily support the Baltimore Defense Center, but many will also be used in the satellite plants and other Westinghouse installations. Established in late 1980, the Technology Center covers 45,580 square feet, including a 13,350 square-foot laboratory, where robots and other new equipment are adapted and programmed for production work and where users are sometimes trained before the equipment goes to the shop floor. Here the laboratory engineers take commercially available robots and equip them with end-effectors and develop the software to control the system.

The Technology Center staff of 250 professionals consists of engineers, computer scientists, systems analysts, and support personnel, including 80 development engineers stationed at various Westinghouse defense group sites around the country.

Union Affiliation

Employees of the Defense Center are organized under three unions: the Salaried Employees Association (SEA), for technicians and clerical workers; the International Union of Electricians (IUE), for hourly workers in the West Building; and the International Brotherhood of Electrical Workers (IBEW) for hourly workers in the East Building.*

II. TRAINING OVERVIEW.

The training described in this study focuses primarily on instruction in the use of programmable automation developed in the Manufacturing Systems and Technology Center and installed in various sections of the Defense Center Operations Division. That technology ranges from a computerized materials-acquisition-and-information-processing system housed in its own Materials

* No specific reason other than "tradition" is given to the question of why two electrical unions have organized the Defense Center's two Baltimore plants.

Acquisition Center two miles from the major production facilities, to robot systems for welding, assembly, and other operations, to "electronic verifiers" for testing discrete components used in electronics assembly. Training for other types of programmable automation--such as computer-aided design, APT (automatically programmed tools) programming, CNC (computer numerical control) and DNC (direct numerical control) machine tools--is also conducted at the Defense Center.

The formal training strategy now being developed for new programmable automation designed at the Technology Center applies primarily to mass training programs affecting all, or at least a majority of, the workers in a location. The Materials Acquisition Center training (described on pp. 14-19) is the major example of such training conducted to date. As computerized materials handling spreads throughout the plant, more training on the Materials Acquisition Center model is expected to take place. Other types of programmable automation developed at the Technology Center directly affect only a few workers, as was the case when eight welders were taught to operate an Automatrix welding robot (see pp. 19-23). In that instance, the training was designed to suit specific conditions in the Feeder Operations area where the robot was installed.

In spite of the obvious differences in approach required to train hundreds of workers, on one hand, and fewer than 10 workers, on the other, the two training programs had common features derived from a shared philosophy of training. As the new formal training strategy becomes commonplace throughout the plant, large- and small-group training is expected to be modeled on a single approach, designed to be adaptable to various conditions and requirements.

This section discusses the Defense Center's training organization and philosophy and gives an overview of the goals of the new training strategy. The particulars of the strategy are contained in the description of the materials acquisition program in Section III, which also describes the robotics training and covers future plans for accommodating the developing plant-wide strategy to small-group as well as mass training.

Training Organization

There are several varieties and levels of training at the Defense Center, conducted or coordinated by full- or part-time trainers with varying reporting requirements. A Personnel Development Department staffed by 11 training professionals runs a battery of classes, seminars, and workshops for management, professional, and clerical personnel. That department also engages in some ongoing, long-term conventional training, like high-voltage soldering and wire-wrap for hourly workers, but does no training for programmable automation. Another department, Human Resources Programs, responds to needs for mass training and assesses and approves all training programs in the Operations Division in order to minimize duplication and allow for program evaluation. Once a need has been identified, the staff runs needs analyses (at the request of operations management) and develops training programs to meet those needs. Those programs are then turned over to the line organization, which has the responsibility of operating the program. To accommodate the growing need for large-group programs to train shopfloor workers in the automated systems developed in the Technology Center, a Human Resources Programs manager has been reassigned to the Manufacturing Systems and Technology Center. Now manager of sociotechnical organizational development, he is responsible for coordinating mass training programs for automation systems developed at the Technology Center and for designing the plant-wide strategy for implementing those programs. Working under him are training coordinators responsible for implementing and monitoring training in the Defense Center Operations Division, the Materials Acquisition Center, and the new satellite plant in Texas (see footnote, p. 3).

Aside from the new-technology training coordinators working out of the Technology Center, many areas in the Operations Division have full-time training managers or coordinators who report to division management, not to a central training department. The activities of those managers/coordinators are varied, depending on the needs of their particular operations area. An extended illustration of the training conducted by one of the divisional training managers shows the range of instructional activities for skilled

workers. In the Feeder Operations Area,* the training manager has developed a system by which workers in the machinist category progress from conventional skills training to NC, CNC, and DNC training. The training modules for the conventional machining courses and the NC/CNC/DNC curricula are based on a list of "competencies" developed by hourly workers. In effect, each worker was asked what he or she had to know in order to do his or her job properly. The training manager also determined, through work with the quality circles, that workers in the Feeder Area learned best through one-to-one teaching. The conventional machine-skills training is a series of self-paced programs in drills, mills, and lathes using proficiency-based task modules.** Trainees in those programs spend an hour each day in a learning center adjacent to the shop floor. Part-time trainers—primarily shopfloor workers who have volunteered for training duties and have taken a "train-the-trainers" course (see p. 8)—grade pre- and post-tests on each module and are available to help the trainees and to answer their questions. Those completing the conventional machining courses and the required amount of shopfloor experience can then enroll in more advanced courses in NC, CNC, and DNC operation. Because of the increased complexity of the course material, the part-time trainers (also shopfloor operators) who teach the 12-week, 1-hour-per-day NC/CNC/DNC courses engage in structured one-to-one training in those machine-specific courses.

Training for eight welders in the Feeder Area in the operation of the Automatix robot was designed by the Feeder Area training manager in close consultation with the vendor trainers and the Technology Center engineers who developed the application hardware and software for the system. The robot training, because it was delivered on a new automated system requiring a new set of skills, was delivered in a series of formal courses taught by the vendor trainers, Technology Center engineers, and the training manager. Now that all of the welders in the department are trained and the robot system is incorporated into the ongoing operations of the Feeder Area, the training manager is working with the Automatix training department to develop a

* Manufacturing activities in the Feeder Operations area include sheet metal fabrication machining, mechanical assembly, and finishing.

** Proficiency-based task modules are designed to teach specific skills required to perform a task. Trainers complete the module by demonstrating their proficiency at performing the tasks.

structured, self-paced training course (using a workbook keyed to audio-visual tapes) for new welders who come into the department. New welders will have the benefit of working with seasoned welding robot operators, and it is expected that they will learn to operate the robot through a combination of on-the-job training and the self-paced robot training now under development. In this way, training for individual welders who will, in the future, learn to operate the robot will be adapted to the already-established training system in the Feeder Area.

Training the Trainers

To cope with the massive retraining demanded by the new technology, the Defense Center contracted with the University of Maryland to develop and deliver a basic course on industrial training. Since January 1982, approximately 250 engineers, supervisors, and hourly operators have taken the 2-day, 16-hour "Train the Trainers" course. The University is now developing a series of seven additional courses, four of which have so far been taught, including one on Task Analysis and one on the Principles of Industrial Instruction. Through these courses, the Defense Center will train engineers, supervisors, and some hourly operators to serve as a "part-time training faculty" when the need arises.

Training Philosophy and Goals

The Operations Division is the chief user of programmable equipment in the Defense Center. Consisting of two major production areas--1) sheet-metal fabrication and mechanical assembly and 2) electronics fabrication and assembly--it is firmly committed to training for the new technology. A major goal of the training efforts, recently established by the division management, is that every person in the division will either give or receive eight hours of training per month. In terms of instruction for hourly workers, that training can range from information processing training, to conventional skills training, to training in specific programmable equipment. For managers, supervisors, and engineers, the range of instruction extends from supervisory skill training, to "train-the-trainer" training, to training in how to deliver specialized instruction on new automated systems to hourly workers (see pp. 16-17).

Worker Involvement and Self-Development

Central to the philosophy of training at the Defense Center is worker/user involvement at the earliest possible stage of the development of training programs and the implementation of new technology. Quality circles, open to all employees, have been in existence since 1979. The quality circles--groups of about 10 people who work together, including a group leader (usually a supervisor) and a third party who acts as a facilitator--meet on company time to find ways of solving work-related problems. Quality circles in various areas of the Defense Center have participated actively in training program design and review. For example, quality circles that included technicians and union representatives reviewed the curriculum for an electronics troubleshooting course (designed to serve all of the over-500 electronics technicians in the plant) before it was finally adopted. Another example is the participation of quality circles in the Feeder Area in developing lists of "competencies" (or proficiency-based tests of the various types of skills needed to perform specific jobs) for the conventional and computer-aided machining courses listed on pp. 6-7.

Now that the quality circles have been operating for the past 4 years, the Defense Center is organizing a "shift in ownership" of the circles. The "third party facilitators," originally Human Resources Operations staff members, have now dropped out, and the supervisors who once served as group leaders have taken over the facilitator roles. The new group leaders are workers chosen by each group from its member-workers. Eventually, the supervisors will also drop out, leaving the "ownership" of the circles to the workers themselves and interacting with the group only when necessary.

User participation is also important in the development of programmable equipment application work conducted at the Technology Center. One example of worker participation in applications development is discussed in detail in the description of the robotics training program on pp. 19-23. Another example is worker input solicited during the final design stages of a computerized

inspection-data-entry (IDE) station.* Eight floor-level users were asked to evaluate the new IDE station before it was finalized. As a result of their suggestions, the location of the menu was modified and the work-area elevation made adjustable, so that an operator, regardless of size, can be comfortably close to the work.** In this and other instances, the advice supplied by the workers enabled the necessary changes to be made before the equipment was moved to the shop floor. Once new equipment is developed, writers in the Technical Data Center rewrite the engineers' technical manuals to an eighth-grade--or lower--reading level for the operators.*** On occasion the operator with the lowest reading level is called in, the system is discussed with him or her, and any instruction the operator does not understand is modified. The manual for a new electronic verification system, for example, is written to a "fifth-grade level" to accommodate the lowest level of reading skills among the workers.

Training in the operations division is also grounded in a philosophy of worker responsibility. A number of technical, managerial, professional, and clerical programs have been developed that require employees to take responsibility for their own career development by identifying their own needs and filling them by taking company-delivered courses. Many departments provide the employees with assistance in identifying the skills they need to perform their own jobs properly or to perform another job they would like to have. Learning Resource Centers are located adjacent to major work areas, each containing a classroom and an audio-visual/library area. Workers may check in to the Resource Centers to put themselves through a brief refresher course on a particular task or skill associated with their current job or--if they are engaged in a

* IDE is a computerized device used in quality control to isolate faulty components on printed circuit boards. It is a subsystem that will eventually be incorporated into the materials acquisition system and shopfloor data collection systems.

** Because the engineer working on the station design was a tall man with a long reach, he had failed to realize the problems a small man or woman would have using the station.

*** According to Defense Center representatives, most newspapers are written at the sixth grade reading level (the Wall Street Journal, they say, is at the tenth grade level). The eighth grade level was chosen for the technical manuals because it seemed most appropriate and readable for high technology documentation.

self-paced training course--to complete a training module. The company provides time on the job for classes related to a worker's present job and provides the same resources after hours, usually from 5 to 7 p.m. or 6 to 8 p.m., for those who want to learn on their own time to acquire new skills to qualify them for other jobs.

Preparing for New Technology: Training for and by Managers and Supervisors

Another aspect of the Defense Center's training philosophy is that, within the next 2 to 3 years, every manager and supervisor will be expected to teach training courses at least 8 hours per month. A number of supervisors and managers have already attended courses in the series on industrial training developed by the University of Maryland (see p. 8); and, as the computerized materials handling and information processing system affects material control in various areas of the plant, more and more supervisors will be called on to teach their workers to utilize the system. The description of the Materials Acquisition Center training program details the process of teaching supervisors how to train their own workers.

The Defense Center also has a supervisory-skill training program, called "Interaction Management," in which managers teach supervisory skills to first-line supervisors. As with the skill training programs for shopfloor workers, the recipients of the training (in this case the supervisors) were consulted on their own perceived needs in the areas of supervisory skills before the program was developed. After a 9-month needs analysis, a program was developed to address the four basic areas of competence identified as required to supervise hourly personnel: technical competence, administrative competence, interpersonal skills, and approach to the job. Also like the skills training programs, the supervisory training is proficiency-based and divided into discrete modules (such as "improving employee performance" and "utilizing effective follow-up action").

A driving force behind the creation of the Interaction Management courses was the recognition that new technology would create changes in the workplace and would require massive amounts of worker retraining. To create what Defense Center representatives call the proper "management culture" to ease the workers through the anticipated changes, the Interaction Management courses

stress such factors as increasing worker motivation, delegating responsibility, and handling emotionally charged situations. Four new modules, recently developed but not yet delivered, were specifically designed to teach supervisors to prepare themselves and their workers for the changes that will be created by the installation of programmable equipment. The new modules address 1) managing change, 2) exploring opportunities for change, 3) overcoming resistance to change, and 4) introducing change. The "managing change" module, for example, teaches supervisors how to plan for self-initiated or upper-management-imposed changes by defining goals, identifying approaches, considering alternatives, communicating the fact of change and the reason for change to employees, consulting employees on the best way to accommodate the change, planning for training that may be required, and evaluating the impact of the change once it has occurred. The four new modules focusing on dealing with change are expected to lead into, or complement, the various courses that teach supervisors how to deliver instruction to their employees.

Open Discussion of the Effects of Programmable Automation

Management candor about what automated equipment, particularly robots, can do and what effect it will have on the work force has made the introduction of new technology relatively painless at the Defense Center, according to a manufacturing engineer who trained the robotic welders. One welding operator noted that two years before the first robot came to the welding department in the Feeder Area, all Defense Center employees saw a film on the use of robots in other countries and what workers' jobs would be like in the future. Eight weeks before the robot's installation, management, aware of welders' fears for job security, frankly discussed Defense Center plans for robotics, assured welders that none of them would lose their jobs, and promised retraining for different jobs if transfers proved necessary. In consequence, the welders welcomed the training opportunity and rapidly became part of what Defense Center representatives refer to as a "team" of welders, programmers, and development engineers who worked in tandem to make the robot a part of the operations of the Feeder Area.

Plant-Wide Training Strategy

The new training strategy designed to ease the introduction of programmable automation grows out of the various aspects of the Defense Center training philosophy outlined above. The ultimate goal is to develop a training approach that will not only be adaptable to varied training needs and situations and to the rapidly changing state-of-the-art, but will also encourage a sense of ownership by both supervisors and workers. The object is to design each individual training program so that it will meet shopfloor needs in the department it serves and to be able to develop new programs rapidly to meet changing needs. The designers of the strategy determined that, since the workers and supervisors in each department know their own needs best, they should in effect "own" their own training programs. "Ownership," here, involves the workers and the supervisors in the program design and means that supervisors are in charge of both selection of trainees and the actual training.* In order to give employees the capability of dealing with the new technology, the designers of the strategy make use of suggestions and reviews by those who will eventually use the systems to enable those users to identify their own needs and communicate to the program designers what they believe they must know in order to do their jobs well.

The details of the new strategy can best be described by example. The following section describes two programmable automation training programs recently delivered at the Defense Center. The first program, Materials Acquisition Center training, is a pilot program for implementing the newly developed strategy in training for large masses of workers. The other program, robot operations training for eight welders, is an example of training that involves only a few workers. In the "Future Capacity" section of the Evaluation (Section IV) is a brief overview of how the plant-wide strategy represented by the Materials Acquisition program is expected to affect even small-group programs like the robotics training (see pp. 34-35).

* In many instances, "selection" is a moot point, since it often occurs that all of the workers affected by programmable automation receive training.

III. MODEL TRAINING PROGRAMS FOR COMPUTER-AIDED TECHNOLOGY

Apart from the obvious differences between a program to train eight welders in robot operations and one which trains over 250 workers to use a computerized information processing system for tracking materials handling, the development and delivery of the two programs share a number of common features. The process of developing and delivering the training programs parallels the process of technology transfer from applications lab to plant floor. In the case of the MAC program, the engineers who developed the applications and the technical documentation got instructor-training so they could serve as "master-trainers." The engineers then trained the supervisors, who, in turn, trained the materials handlers. In the case of the robot training, a team concept was employed, with manufacturing engineers and the training manager for the Feeder Area participating in a series of orientation and training sessions for all eight welders in the division's welding department. In both cases, the users were involved at the earliest possible stage of applications development and/or training program design. In the case of the Materials Acquisition Center, managers and supervisors reviewed the lesson plans, user's manual, and training aids and made suggestions to improve their clarity and ease of use. In the robot training, the welders received part of their training while the robot was still in the applications lab and helped the development engineers to fine-tune the applications development to meet shopfloor needs (see pp. 21-22 for details).

Materials Acquisition Center (MAC): Large Group Training Model

In November 1982, the Defense Center opened a 113,000 square-foot Materials Acquisition Center, equipped with a centralized information processing system that eliminates much of the paperwork demanded in materials handling. The center is responsible for delivering kits of already inspected and tested components and other material to the manufacturing operation in Baltimore and the new plant in Texas. By 1985, materials handling, inspection, and testing will be automated.

Goals

The training program developed for the Materials Acquisition Center had a double goal: the first and most immediate goal was to train large numbers of materials handlers to work with MAC's information processing system; the second, longer-term, goal was to establish a structured yet flexible mass training program model that could be readily adapted to future large-scale programmable automation installations affecting a large number of workers. Both goals focused on designing a process whereby many workers could be trained quickly and efficiently with minimal disruption of normal operating procedures. In addition, the MAC program (and others to be modeled on it in the future) were to be designed to meet the needs of the managers, supervisors, and workers who would use and "own" both the system and the training program.

The training "process" developed for MAC included procedures for designing the curriculum and procedures for training the instructors and the workers. Both procedures are aspects of the model for future training programs and have been designed to streamline and enhance the Defense Center's overall programmable automation training capacity. Both aspects of the process are described below.

Curriculum and Instructor Development

The necessity for developing a program to train masses of materials handlers--the majority of whom had little or no prior technical or computer training--in the shortest period of time resulted in a system that makes use of already existing organizational relationships and procedures and adapting them to serve the need for formalized training programs. In terms of curriculum development, the process was as follows: the technical specifications written by the engineers in the Manufacturing Systems and Technology Center were passed along to writers in the Technology Center's Technical Data Center. The technical writers developed the engineers' technical documentation into a user's manual, written to an eighth-grade reading level and broken down into modules, each one covering a specific task (such as "processing receivable materials at the receiving dock" or "material retrieval"). The user manual then became the basis for highly structured lesson plans developed by interns,

M.A. or Ph.D. students in education from local colleges and universities." Like the user's manuals, the lesson plans are divided into task modules. Like other Defense Center training guides, they are proficiency-based, which means that the trainees learn to perform the task during the course of the lesson and their proficiency in accomplishing the task is checked by performance. The lesson plans provide the instructors with talking points for introductory and connecting narratives, instructions on how and when to use visual aids, and step-by-step procedures for taking the trainees through the task contained in each module.

The lesson plans relieve the trainers of the burden of preparing lessons and insure that all trainees learn the same material. The detailed, highly structured curriculum was especially necessary because all of the instructors are first-line supervisors, not professional trainers. The use of supervisors as part-time trainers was both a necessity and a logical extension of existing organizational relationships. The supervisors, who had a traditional on-the-job training relationship with their workers, first went to the "Train-the-Trainers" course delivered at the Defense Center by University of Maryland faculty. They then attended in-plant instructor training on the Materials Acquisition System to learn how to deliver the formal training courses. A "systems approach" was used to train the supervisors/trainers. The engineers and technical personnel who developed the system--who also attended the University of Maryland "Train-the-Trainers" course--served as master-trainers. Using the lesson plans developed by the interns, the engineers taught the department supervisors how to perform all of the tasks involved in operating the entire system. (This is in contrast to worker training which covers only those tasks necessary to perform particular jobs.) The utilization of the development engineers as master-trainers served a multiple purpose: it gave the engineers an opportunity to review the lesson plans to make sure that they were technically correct; it gave them experience in explaining highly technical subjects to non-experts in layman's terms; and it

* The unpaid interns received graduate credit for the curriculum development work. The intern system--supported by eight educational institutions--is an ongoing program developed to provide work experience to graduate students and to aid the Technology Center in training program development, needs assessment, and other activities.

provided an opportunity for direct exchange of information between the developers and users of the system.

The supervisor training program was a 32-hour course consisting of a three-part process: 1) demonstrations of the system, 2) lectures (based on the lesson plans) and hands-on training to teach proficiency over the entire system, and 3) practice sessions during which the supervisors trained each other. A total of 30 supervisors were trained.

Training Facility

The materials acquisition training facility is a 35' by 45' divided room located next to the work area. One side is a classroom seating 45 people; the other is a hands-on training area equipped with nine Hewlett-Packard and IBM terminals and two printers.

Selection and Scheduling

MAC was designed to centralize materials acquisition functions, which had previously been dispersed throughout various sections of the Defense Center. The workers who received training were, therefore, the materials handlers in old materials acquisition sections. The training of the workers and their transfer to MAC was done in stages: workers responsible for processing newly received materials were trained first, and workers responsible for other functions--such as testing the incoming materials--were trained in later stages.

Curriculum and Teaching Methods

The lesson plans and user manuals that form the core of the instructional material used by the supervisor/trainers cover the use of MAC's management information system and the operation of the Hewlett-Packard and IBM terminals that access the system. Following a 2-1/2 hour terminal operations session taken by all workers, the supervisors trained the workers in precisely those tasks they would be performing. The user manual and the lesson-plan book are broken down into five major sections: 1) an introductory and summary section, including a system overview, an explanation of system messages, a review of

the menu layout, basic instructions for entering and leaving the system, and a summary of system functions, 2) a section on how to process materials, 3) distribution of materials, 4) support functions, such as how to do verification inquiries-and-updates and material distribution updates, and 5) a section on how to file reports (such as a missing bin location report) associated with materials acquisition.

Each section is further broken down into discrete tasks, each of which is a computer "transaction." The "Processing Materials" section, for example, contains 7 lessons covering 7 transactions that may be required for initial materials processing. The first lesson, "processing receivable materials at the receiving dock," is approximately 45 minutes long and includes a complete review of how to process correctly packaged and labeled materials. The lesson is, essentially, a script for the instructor to use as he or she takes the students through an introduction to the procedure, a slide demonstration, step-by-step directions, question-and-answer periods, and hands-on practice. Other modules in the processing materials section cover such transactions as processing non-receivable materials and receiving office notification of non-receivables.

In order to gear the training specifically to the workers' new jobs, workers learn only those transactions necessary for their particular jobs, not the whole system. When workers are rotated, or when new workers arrive, supervisors select the transactions they will need for the new job and teach only those. This is not, however, intended to restrict the workers' flexibility and general skills-development but to make the most efficient use of training time to teach workers precisely what they need to know to do their jobs (see pp. 27-28 for further discussion).

Results

Approximately 250 hourly workers have been trained to date. Very few problems have occurred, either with the training of the master trainers, the supervisor/trainers, or the workers. According to the Technology Center's manager of sociotechnical organizational development, although development engineers and technicians (the master trainers) normally tend to take shortcuts when explaining systems they know intimately, the highly structured

lesson plans kept them from skipping steps or becoming too esoteric in their descriptions of the system. Only one supervisor/trainer objected to following the lesson plans, believing that he could do better without them. As it turned out, however, the root of his problem was fear of teaching to a large group rather than the one-to-one on-the-job type of instruction to which he was accustomed. Eventually, he returned to take additional instructor training, which resolved the problem.*

Robotics: Small Group Training

In 1982 the Defense Center introduced an Automatix Robovision II welding robot in its Feeder Area. The robot can weld 60 inches a minute, with better and more consistent quality of penetration at the joint than that achieved by manual welding techniques, which, at best, cover only eight to ten inches a minute. As an additional time-saver, the robot welds one part on the first positioner, while the operator is taking a finished part off the second positioner and putting on another. According to both Westinghouse and Automatix representatives, it is the first off-line programmed production robot in the country. The robot is programmed using a Computervision interactive graphics system. Programs are stored in central computers and are transmitted directly to the robot's controller via a direct numerical control (DNC) link. The entire system consists of the robot, two Westinghouse welding positioners, a Millar Pulse-Star power supply (adapted by Technology Center engineers to meet the Feeder Area's welding requirements), a Cobramatic gas-metal-arc welding gun, and the Automatix controller (which controls the robot motion, the positioner table motion, the welding process, and communication with other computers).

* Although supervisors are expected to teach and encouraged to teach, no one is forced to deliver formal instruction. Training facilitators or other supervisors can take over a reluctant supervisor's training duties. It is, however, expected that those who resist training duties for whatever reason will eventually learn to handle them. No unresolvable problems in this area of the MAC training have occurred to date. (See pp. 28-29 for further discussion.)

Goals

The major goal was to provide trainees with fundamental knowledge of how the Automatix system works and how to interact with the robot controller and the two positioners that hold the part being welded. A further goal was to lessen worker anxiety about job security related to the introduction of robots in the industrial setting.

In-Plant Training Staff and Vendor Participation

The training staff consisted of the Feeder Area training manager and two development engineers, one with a background in computer systems, the other in biomedical engineering. The in-house training staff was aided by the manager of training and communication from Automatix, the robot vendor.

Automatix participated in several aspects of the training, providing at its training facility one week of operations-and-maintenance training for two manufacturing engineers (included in the purchase price of the robot) and 2-1/2 days of maintenance training for two maintenance technicians.* The Automatix training manager took part in the Technology Center orientation and taught the 3-day classroom session for the hourly workers on-site at the Defense Center. In addition, the development engineer and training manager designed a customized curriculum to use in training the hourly workers.

Training Facilities

Training of hourly workers took place in three areas: in the Technology Center laboratory, while engineers were still programming the robot and interfacing it with appropriate end-effectors; in the Learning Resource Center in the Feeder Area; and in the welding department after the robot was installed on the floor.

* See Case Study #13 for a description of Automatix training and products.

Selection

To allay any fears about job security, all eight welders in the sheet-metal fabrication area received training.

Curriculum and Training Methodology

Two months before the robot was installed, the eight welders, along with the chief union steward, the welding foreman, NC programmers, the Feeder Area manager, and several other management and engineering personnel, went to the Technology Center for an orientation to robotics. During the half-day session, participants heard discussions of what a robot is, its function, the future of robotics in the Defense Center, the workers' roles in the development of robotics, and programming procedures. Technology Center development engineers, supported by the vendor training manager, demonstrated how the robot works; and participants were allowed to type in commands to put the robot through its paces and to use a teach pendant to manipulate an IBM training robot.

The half-day orientation was followed by 3 days of classroom sessions for 3 hours per day, delivered by the Automatix manager of training and Westinghouse personnel. Using task-oriented manuals, vocabulary sheets, and exercises, he took the trainees step-by-step through the general theory of robotics, the specifics of the Automatix system, how to call up and run a program, troubleshooting, and safety procedures. Immediately after the three days of intensive classroom work, a series of 6 2-hour follow-up classes began. Taught by manufacturing engineers, the once-a-week sessions were designed to review in more leisurely fashion the material covered in the three-day course. By the end of the second week of follow-up classes, the robot was installed on the shop floor, and training moved from the classroom to the robot's welding booth for the next 8 weeks. Instead of merely talking about robotic welding and studying manuals, the trainees worked with development engineers and the instructors in 2 hour hands-on practice sessions, 1 day per week for 8 weeks. During the 8 weeks, while engineers were going through the final steps to make the robot operational, the welders working in the area began to ask questions, to make suggestions, and (if they happened to be standing by the console) to

help by typing in commands at the engineers' request. In this informal way, the hands-on training approached 8 hours per day, and the welders contributed some suggestions that helped the engineers fine-tune the system. For example, suggestions made by welders observing the engineers' attempts to solve a recurrent problem with the tips of the welding torch helped the engineers to locate the source of the problem.

In conjunction with the operator training, NC programmers in the Feeder Area were trained to write computer graphics programs for the robot. The programmers, who had prior experience in programming NC tool paths using CAD systems, were taught by the software development engineers to work with the Technology Center-designed robot programming software package. When the robot became operational on November 5, 1982, an hourly operator downloaded the first job by direct numerical control (DNC), ran the part, and got it inspected.

Evaluation, Certification, and Follow-Up

No formal classroom tests were scheduled. Once training was completed, the welders took a hands-on test, showing that they could use the software to manipulate the robot through the welding test and that they knew how to employ the user-friendly "help" file that guides a welder who is unsure of the operational sequence. The in-house Quality Engineering Department certified those who pass as qualified, according to military specification 495, for working on automated welding machinery.

There is no formal follow-up to gauge the adequacy of training. Informal follow-up comes from the Technology Center engineers who taught the course and worked with the operators, shopfloor engineers, and programmers to debug the system. According to one of the Technology Center engineers who has been with the project from its earliest stages, the follow-up provided by the development team, while it is informal, is also both "urgent" and "interactive." When they deliver new computer-aided systems to an operating division, Technology Center engineers are essentially acting as a vendor delivering a system to a customer. "Customer satisfaction" is, therefore, extremely important, and Technology Center representatives work with the recipients of the system to set up "acceptance criteria" for the system, which

includes a listing of the functions the system is expected to perform, user documentation, and training. Today, over 6 months after the system was installed, Technology Center engineers still spend some time at the Feeder Operations area working with the off-line programmers (NC programmers who worked with the engineers to learn how to program the 5-axis robot) and providing whatever other assistance is necessary.

Results and Trainee Comments

Six welders have completed training and passed the certification test and two have dropped out after bidding successfully on higher-paying inspectors' jobs.

The weeks since the robot became operational have revealed only minor problems. Some operators have found a few entries in the "help" file, which they call up for assistance, to be ambiguous. These have now been rewritten to the welders' specifications. A second problem has been the welders' fear that they would lose their manual welding skills. According to a development engineer who taught the course, however, robots can never completely eliminate the need for skilled workers at the Defense Center, which operates in a batch mode, much like a job-shop. First, the process is inexact and difficult to quantify -- almost intuitive; thus, skilled welders are still needed to recognize such problems as too much argon shielding gas going into the robotic welder or an inadequate pool of welding material. They must know what the problem is, how to solve it, and how to change the computer commands to achieve the solution. According to the development engineer, they need the same skills as those needed for manual welding, but they apply them in a different way. Second, it is not economically feasible to automate all welding jobs. Westinghouse engineers estimate that about 20 percent of welding jobs will remain manual, either because of the configuration or tooling required or because various metals require different handling.

To give every welder a chance to work on the robot and to further allay their apprehensions about losing their manual skills, the Feeder Area management has been rotating the welders through the robot-room periodically, thus giving everyone an opportunity to both operate the robot and continue to do manual welding. In addition, to give the welders maximum control over the robot, the software was written so that the operator selects all of the weld parameters

and is personally responsible for inspecting each welded part as it comes off the system. One trainee felt that the robotic welding certification would help him to move ahead in his career, and others referred to the "challenge" of working with computers and the computer skills they gained.

IV. EVALUATION OF PRESENT AND FUTURE PROGRAMMABLE AUTOMATION TRAINING CAPACITY

The Defense Center is introducing new technology with very few discernible adverse effects--and those that are evident appear to be minor. Among the reasons for that are the following: 1) as a DOD contractor, the Center can pass on training costs to the customer as part of overhead, 2) what appear to be excellent company-union relationships,* 3) early involvement of hourly workers in the development of both training programs and programmable equipment application work, and 4) the Center's commitment to retraining and employment for every worker displaced by programmable automation. The key elements in the equation, however, are the training approaches exemplified by the Materials Acquisition and the robot operations training programs. This section is devoted primarily to an evaluation of those approaches. Also included are union and evaluations of the overall training scheme,** and a concluding statement addressing the Defense Center's potential capacity to meet future training needs.

Training Approaches

The Defense Center's approach to mass training is being developed in response to the vastly increased training necessary to cope with the move toward the paperless factory (created by the Center's computer-aided management systems) and with the various computer-aided manufacturing, design, inspection, and testing equipment under development or planned for the future. Before 1980, hourly workers were trained primarily by an informal on-the-job method. Supervisors and fellow workers trained new personnel on existing equipment, and when new equipment was introduced, workers received training from an

* This is verified by IBEW and IUE representatives.

** Trainee evaluations of the robotics course are included in the program description section, pp. 23-24.

engineer or foreman or were given vendor training. The computer-aided management system and the programmable automation planned for shopfloor use introduced the need for a formal system to replace the previous informal system. On-the-job training is slow, and Defense Center representatives anticipated the need to train large numbers of employees in a short period of time. Furthermore, the volume of information that the workers must absorb and the nature of the skills required (whether they are computer transaction skills delivered to workers in the materials acquisition center or robot-programming-and-operation skills) necessitated structured training programs to ensure that the material would be covered completely and consistently.

In essence, the strategy adopted by the Defense Center maintained the traditional instructor-trainee relationship of informal on-the-job training--in which supervisors train their employees on the job and engineers and foremen deliver new equipment training--but gives the engineers and supervisors a structured methodology and curriculum that enable them to deliver the formalized courses required for new technology training. Thus, the training strategy capitalizes on and develops ahead-existing relationships, keeps the training itself as close to the job as possible, and gears it to the needs of the users. In addition, the strategy allows the Defense Center to move quickly into a formal training mode since it bypasses the necessity of hiring professional trainers and then training them in Defense Center operating procedures and training requirements for the specific programmable equipment to be installed. Aside from the money- and time-savings involved, the strategy gets extra mileage out of large group training by operating on a pyramid principle: 1 master-trainer (engineer) can train 3 trainers (supervisors), each of whom can train 30 workers.

Benefits of the Defense Center Approaches

The Defense Center's approaches have produced a number of benefits, some of which were noted above (i.e., it made use of existing relationships; it enabled the Center to move quickly; and the training itself is user-oriented and kept close to the job site). Other benefits are addressed below.

Reduction of Scheduling and Selection Problems. In the large-group training model, in which the supervisors are responsible both for selecting the trainees and for delivering the training, the problem noted by numerous in-plant and vendor-trainers of not having control over trainee selection is virtually eliminated. Selection problems were eliminated in the small-group model by training all of the welders in the Feeder Area rather than selecting workers according to seniority or skill-level. Scheduling, too, is simplified since courses can be structured into the work flow more easily than if delivered by a formal training department.

User/Worker Involvement. User involvement in the early stages of program design and, in many instances, in the applications development stage makes the training more responsive to users' needs and often helps researchers and curriculum designers to do a more thorough job. The obvious benefit of user involvement in the applications stage is that changes can be made cheaply while the equipment is still under development—"before we start cutting metal and things harden," as the Lead Engineer for Electrical and Computer Systems put it. A further benefit is increased worker acceptance of new technology. Familiarity with a system early in its development and a sense of being part of the team have, in many instances, lessened workers' fears of displacement and of damaging the equipment or obliterating the manufacturing data base by pushing the wrong button.

Flexibility Combined with Systematic Coverage. The large group training strategy is designed to be both flexible and systematic. The curriculum-writing process--whereby the engineers' technical documentation was rewritten by Technical Data Center writers into users' manuals, which in turn became the basis for lesson plans written by university interns--will soon be applied to all training programs for systems developed in the Technology Center. The use of the development engineers as master trainers in both the small- and large-group programs indicates that the training will be adapted to the requirements of each new system, while the use of supervisors as trainers in the large-group programs and the solicitations of suggestions by users prior to training delivery indicates that the training will continue to be adapted to meet specific users' needs. At the same time, the trainers are given a structured

curriculum to use in their classes, so that all trainees will get the same information and that continuity from one training segment to another is ensured. In addition, the structured curriculum relieves the trainers from the necessity of advance preparation.

Combination of Systems Approach and Task-Oriented Training. For large installations requiring mass training, such as the Materials Acquisition Center, the managers and supervisors receive proficiency-based training in the operation of the system as a whole (and how it integrates into the Center-wide computer-integrated system). Both engineers and supervisors learn to deliver instruction on the entire system and to be in command of all of the information in the user's manual, which covers the system as a whole. The supervisor then uses the training lesson plans (which are based on the user's manuals) to teach his or her employees. Since the manuals and lesson plans are divided into modules covering specific groups of tasks, the supervisor can select which modules to teach workers who will be performing specific tasks. When a new worker enters the department, or when workers are rotated to other duties within the department, the supervisor selects the specific modules needed to teach them the new or different tasks and conducts the training on an as-needed basis.

A proficiency-based, task-oriented approach is also taken when training small groups of skilled workers. In the robotic welding program, for example, the formal training covered those specific tasks the welders would be responsible for performing on the job. This was done for a variety of reasons, the most important of which was that it was the most effective means of providing the skills and knowledge needed to operate a complex system in the shortest amount of time. It is important to note, however, that any welder who wants to obtain a more complete knowledge of the entire system is encouraged to take advantage of informal information-and-training channels set up between the welders and Technology Center development engineers and shopfloor engineers (who have been educated in the workings of the system as a whole). The welders have constant access to the shopfloor engineers, who provide them with any additional systems information they request. The welders also have access to the development engineers should they need or want information beyond the

knowledge of the shopfloor engineers. Similarly, interested workers who have received task-specific materials acquisition training may request their supervisors to provide them with additional informal training and a broader knowledge of the MAC system. According to Defense Center representatives, any such request for additional training and/or information will be accommodated within reasonable limits.

Defense Center representatives believe that the above approach—which employs task-specific training as 1) a means of providing "need-to-know" information for all workers directly affected by programmable automation, and 2) a basis for additional informal training for those workers who want to learn about the system as a whole—offers both efficiency and flexibility and gives workers the opportunity to acquire information that goes beyond their formal job-related responsibilities when they, themselves, feel it is necessary or desirable.

Incorporation of Training Strategy into Operations and Development Strategy.

The training strategy, since it follows the path of the technology from applications development to plant floor implementation, is part of the Center's development and operations processes. The training strategy is, in fact, modeled on the technology transfer flow. This indicates that the training will not lag behind technology implementation and that training is looked upon as a vital part of the operation as a whole. In addition, when training is delivered at the end of the applications development stage, as was the case in the robot training, the workers are trained and ready to use the equipment as soon as it becomes operational.

Drawbacks/Problems

While the new training strategy has, to date, produced more benefits than problems, there are some actual and potential drawbacks to the plan. These are cited below.

Drawbacks of Decentralized Training. Some Westinghouse representatives believe that a centralized training department--as opposed to the decentralized training conducted under the new strategy--would avoid the overlap of training programs that sometimes occurs and would create a department with a broader perspective on training needs. Those representatives also believe that a centralized training department would give a wider range to the talents and expertise of trainers and facilitators who are now confined to one division, department, or area. On the other hand, these same people recognize that a centralized department could not respond as quickly as the current system does to specific training needs and could not handle the massive training demanded by the new technology unless it were an extremely large department (which would be difficult to justify in terms of corporate budget).

Resistance on the Part of Some Supervisors to Training Responsibilities; Inadequate Performance by Individual Trainer/Supervisors. While none of the supervisor/trainers in the materials acquisition program exhibited resistance to taking on training duties, one showed a reluctance to follow the structured lesson plans. The first sessions delivered by that supervisor were, according to facilitators who monitored his classes, "a disaster." After repeating the materials-acquisition instructor-training course, however, his teaching improved and his resistance to formal classroom instruction lessened. Although 30 supervisors participated in the MAC training with only one problem, and although an estimated 50 percent of the Defense Center's over 300 supervisors currently deliver some type of training (either on-the-job or in formal classrooms), the potential for supervisor resistance still exists. Some Defense Center representatives believe that shopfloor operators or programmers may make better and more willing trainers than some supervisors. Nevertheless, while operators will still have the opportunity to be trainers in programs like the machining series in the Feeder Area, it is an Operations Division policy that all supervisors and managers eventually engage in training. This requirement is likely to become more important as the computerized materials-handling-and-control system is installed in

more and more departments--not only to ensure that the supervisors have a thorough knowledge of the new system, but to ease potential scheduling problems. Defense Center representatives responsible for implementing the policy believe that the supervisory skill courses and the train-the-trainer courses will eliminate the majority of the problems. In addition, individual assistance will be given to those who need it. They further point out that, over the last 3 years, upper management has made a concerted effort to prime the first-line supervisors to take an active role in training and to work on increasing their ability to communicate with and involve the workers in various other activities relating to operations (such as quality control, safety, and work flow). Proponents of the supervisor/trainer system believe that the work of the past three years will pay off by encouraging supervisors to accept training responsibilities with little or no resistance. If the MAC training program is well-received as a model, few such problems are likely to exist. Until the supervisor/training requirement becomes more widespread, however, no final conclusions can be drawn.

Another potential drawback--that training is delivered by supervisors and engineers who are not professional trainers--appears to be outweighed by the benefits of the new training strategy. In the first place, a staff of fully professional trainers could not have been developed soon enough to meet the need for the massive training required for the new automated systems. Secondly, a more relaxed training atmosphere can be achieved if the trainer is someone whom the trainees work with on a daily basis. Third, supervisors are more likely to have an intimate knowledge of the procedures in their own departments than trainers attached to a centralized training department. In addition, the well-structured lesson plans leave little room for error and give the trainer/supervisors the confidence of knowing that all of the

material they need is laid out clearly before them.* Also, since the instruction is designed to be proficiency-based, much of the learning is accomplished by having the trainees perform each piece of the task until they have correctly completed the task as a whole. Finally, technical specialists are on hand to observe each class the first few times the instructors teach. If they miss any steps or are asked a question they cannot answer, the observers will step in to aid them.

Union Evaluation of Training

Both the IUE and the IBEW are supportive of the Defense Center training for hourly workers. The president of IUE Local 130 notes that the company always informs the union five or six months in advance of plans to install and train for new equipment. His local, he says, welcomes automation because it seems to make the Defense Center more competitive, creating more jobs and giving more job security. These new jobs will be done in the bargaining unit, according to a commitment made to the IUE International at the time of the 1982 contract negotiations.

The National Director of the Manufacturing Department of the IBEW also points out that automation at the Defense Center does not threaten job security because workers, given a chance to protect their jobs by retraining, can "just about choose their own field." If the IBEW were designing a program to minimize the psychological effects of automation and protect workers' jobs, he says, "this would be it."

Future Capacity

Although the Defense Center's plant-wide training strategy is not entirely free of problems, the problems that have occurred to date are minor, and the pilot programs appear to be operating smoothly. The ultimate goal--that every person in the operations division will either give or receive 8 hours of training each month--has not yet been met, but Defense Center representatives

* Apart from setting-out the lesson in step-by-step fashion, the lesson plans list each item of material (such as packing slips, worksheets, pencils, projector, slides, etc.) the instructor will need.

estimate that approximately 50 percent of the operations workforce are currently engaged in training and that universal training participation should be achieved by 1986.

Future capacity appears to be high for a variety of reasons. First, the plan is designed to be infinitely expandable: if each supervisor is trained to instruct his or her own workers, the Center can accommodate new mass-training needs without either overtaxing a centralized training department or creating a large training section which may, at some future time, have to be pruned. Because the training process follows the technology itself from applications development to shopfloor installation--and because the training strategy is fully integrated into the development and operations plan--it is likely that future training needs can be accommodated as they arise. In addition, the provisions for both flexibility and a structured approach indicate that the strategy has the capacity to meet widely varied future training needs--even those that are, at present, unknown.

Some of those future training needs are known, since the Manufacturing Systems and Technology Center is currently working on a number of new programmable automation applications due to be installed in either the Baltimore or the Texas plant, or both, in the near future. The following section gives an overview of new technology development, followed by a brief description of the training expected to accompany it.

Programmable Automation Under Development as Part of the Air Force Technology Modernization (TechMod) Program

The systems described below are part of the technology modernization program sponsored at the Defense Center by the U. S. Air Force. The \$7 million Air Force contract has stimulated the development of advanced automation systems. To expand the TechMod program further, Westinghouse has invested substantial additional funds in the program and plans to increase that in the future.

The first part of the program is Materials Accountability and Robotic Kitting (MARK); "kitting" refers to the preparation of kits of electronic components. Using a bar code like that employed in supermarkets, MARK will

automate the process of extracting printed-circuit board (PCB) components from bulk storage, preparing the kits, and shipping them. The system is scheduled to be installed in the new Texas plant in 1984 and in the Baltimore Materials Acquisition Center in 1985.

The Standard Electronic-Assembly System (SEAS), the second part of the TechMod program, will use robots and automated-materials-handling techniques to install components on printed circuit boards. Helped by television cameras (aimed up, down, or horizontally) that sense the position of components, the robots will insert component leads in holes of PCBs where clearance is only a few thousandths of an inch. Engineers at the Technology Center are now adapting an Automatix A600 robot and a Westinghouse 5000 dual-arm robot for use in SEAS, plus peripherals like vision systems, automated alignment systems and lead-cutter clinches. Pilot models of both robots and their associated peripherals will be operational in August 1983 at either the Baltimore or the Texas plant.

The Robotic-Enabled Assembly of Cables and Harnesses (REACH), the third part of the TechMod program, will automate the production of 205 different designs of cables and harnesses, produced primarily for the APG-66 radar used in the General Dynamics F-16. About 80 percent of the 1,300-2,500 cables and harnesses now manufactured each month in the Defense Center require some reworking. When REACH is installed at a satellite plant near Baltimore in summer 1984, six to ten Westinghouse 5000 or 6000 robots in an integrated, flexible, user-friendly system will completely automate the production of cables and harnesses.

Technology Center engineers are also working to adapt a Unimation PUMA 500 robot to be used as a pilot model for flat-pak assembly, where the robot places electronic components on a circuit board. The prototype became operational in February 1983 and the production model, which will employ a Westinghouse 1,000 robot, will be ready by summer 1983. Another robot being developed at Technology Center is the Fujitsu Fanuc Model 1, used to load and unload heavy metal on milling machines.

Proposed Future Training for the Texas and Baltimore Plants

Most of the training for the automated Texas plant and for TechMod equipment will follow the procedure developed for the Materials Acquisition Center. The only difference will be that in the Texas plant team-advisers, rather than first-line supervisors, will train teams of technicians.* Each department in the plant will be organized around semi-autonomous groups, each of which runs its own operation, rather as a quality circle does. Team-advisers, who are on hand to guide and advise the groups, will be trained by development engineers serving as master trainers.

Current plans in the Baltimore plant call for all mass training programs to be developed on the model of the materials acquisition training. For small group training, like the robot operations program, the strategy will be modified to suit the needs of small groups and the conditions existing in the area in which the equipment will be installed. It is unlikely, for example, that supervisors will be called upon to act as trainers when only a few employees are to be trained. As was done in the welding robot program, Technology Center development engineers, the department training manager, and possibly shopfloor engineers will deliver training to the workers directly. One aspect of the training strategy that was not incorporated into the robotics program but will be a part of future small-group training is the curriculum writing process employed in the MAC training, in which university interns wrote structured lesson plans, which were then reviewed by the development engineers and used by them to train the workers. Another part of the strategy as it will be applied to small groups calls for "mass education" for all of the workers in the department who will be indirectly affected by the new system. "Mass education" means that those workers who will not be operating the system but who will be working in its vicinity will attend lectures and discussions covering safety, how the system may indirectly affect their jobs, an overview

* All of the employees in the Texas plant are salaried technicians and engineers. No hourly workers will be employed.

of what the system does and how it functions, and future plans for increasing the automation in their work area.*

Defense Center management representatives believe that three ongoing activities will work together to increase the Center's manufacturing capacity, the quality of its products, and the productivity of the workforce. Those activities are 1) the work being done by the quality circles, which will soon be controlled entirely by the workers, 2) the efforts to improve the administrative, interpersonal, and technical skills of managers, first-line supervisors, and project leaders (engineers) in the Interaction Management courses, and 3) the technological advances being achieved by the Technology Center staff, which result in "process consolidation" (the combination of separate processes into a single consolidated process and the consolidation of previously separate work-areas into a unified work area). The Feeder Area, for example, is already planning on moving its cable production area to a new REACH facility (see p. 32) and phasing out old operations which will no longer be required. All of the workers in the affected areas will be retrained and moved to either the REACH facility or to another operation. All Feeder Area workers are informed of the progress of the consolidation via the Feeder Area newsletter and other means. Managers and supervisors who are learning how to deal with changes in the workplace in the Interaction Management courses will be trained in techniques that can ease the workers' transition, and the quality circles provide a channel for the workers themselves to deal with problems that may accompany the move.

Perhaps the most significant aspect of the technical training system at the Defense Center is that it is supported by--and, in its turn, supports--other activities like those mentioned above. Plans for technology expansion are accompanied by training strategies. Displaced workers are retrained rather than laid off, and both managers and workers are provided with means of dealing with the changes occasioned by programmable automation. Although it is too early to determine whether the new training strategy will be flexible

* The robot program did contain an "educational" component similar to that described above, but it was orchestrated by the Feeder Area training manager. In the future, the Technology Center staff in charge of training for new technology will provide assistance for such activities.

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enough to accommodate all future training programs or whether future training delivered by engineers and supervisors who are not professional trainers will be successful, it appears that the Defense Center management and those responsible for training in various internal organizations have done everything possible to make sure that training does not lag behind technological advances. That, in itself, is a rare achievement.

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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION,
AND THE WORKPLACE

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- C.13--PROGRAMMABLE CONTROLLER TRAINING PROGRAM: INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11, AND LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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**Employment, Education,
and the Workplace**

Volume II—Working Papers

**Part C: Individual Education and Training Case
Studies**

C.12— Texas Instruments

This is an OTA Working Paper that has neither been reviewed nor
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COMPUTERIZED MANUFACTURING AUTOMATION: EMPLOYMENT, EDUCATION
AND THE WORKPLACE

Case Study for:
TEXAS INSTRUMENTS

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
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FINAL VERSION

Education and Training Case Study Series

Computerized Manufacturing Automation:
Employment, Education, and the Workplace

Prepared by

N. Jeanne Argoff, Ph.D

Office of Technology Assessment
U.S. Congress
Washington, D.C.

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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

TEXAS INSTRUMENTS INCORPORATED

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TEXAS INSTRUMENTS INCORPORATED

COOPERATIVE PROGRAMS WITH EDUCATIONAL INSTITUTIONS

INTRODUCTION

Texas Instruments (TI) delivers an extensive series of training and education programs to its employees, customers, and commercial users. The object of this report, however, is to describe the company's cooperative relationships with educational institutions at all levels--from primary schools to universities. While the descriptive portions cover a wide variety of programs and activities, they are not intended to provide a comprehensive coverage of all such programs that Texas Instruments participates in or sponsors.

Section I presents a brief description of the company and its philosophy of education and training. Sections II-IV describe specific TI programs in universities, 2-year colleges, and in the Dallas public school system (specifically, grades 4-12). Section II focuses primarily on an integrated circuit design program that began at Texas A & M University and has now spread to four other universities. Section III covers a joint program with Eastfield Community College to train printed circuit board designers, who from the time they begin their education at Eastfield, are placed on the TI payroll as full-time employees. Both the A & M and the Eastfield programs involve computer-aided design, testing, and verification techniques. Section IV discusses TI's initiation of and participation in a Dallas Independent School District project to "create a favorable image of math and technology" among grade school students to encourage them to pursue mathematics-based technical curricula in high school and beyond. Also discussed in Section IV are TI's involvement in Dallas' "magnet high school" program--which provides 3-hours-a-day of specialized study for gifted students in science-and-engineering--and in other activities aimed at improving the interest and participation of high school students in mathematics and technology programs. Section V evaluates, in general terms, TI's capacity to work with educational institutions and discusses near- and long-term benefits of the industry-education alliances described in Sections II-IV.

I. COMPANY BACKGROUND AND OVERVIEW OF EDUCATION AND TRAINING ACTIVITIES

Company Background

Texas Instruments, headquartered in Dallas, employs over 30,000 people in 50 plants located in 17 countries. Ranked 79th in the Fortune 500, the company had total sales in excess of \$4.3 billion in 1982. TI's home and business computers are well known, as are its hand-held calculators and computerized learning aids. While digital products, such as the minicomputers and other consumer electronics products, brought in over \$1 billion in sales, TI's "component products"—semiconductors, such as integrated circuits and electrical and electronic control devices—account for an even larger portion of its net sales. Other products include government electronics (radar, infrared surveillance systems and missile guidance-and-control systems); and metallurgical materials used in automotive equipment, appliances, and telecommunications equipment. TI also provides geophysical services—primarily, electronic collection and processing of seismic data in connection with petroleum exploration.

Education and Training Overview

According to the corporate manager of training and education, Texas Instruments has two major missions in the field of education and training. The first is to provide TI employees with the training required to enable them to meet organizational goals of product quality and operating efficiency. This is achieved through a wide variety of internal training programs at all levels* and through company-supported education at colleges and universities. Approximately 50 percent of TI's internal training programs are computer-related—ranging from PASCAL computer language training (for programmers, engineers, operators, and maintenance personnel who work with robots and computer-aided manufacturing equipment) to micro-electronics training (for employees who design hardware or write software for

* Approximately 10 percent of the internal training activity is management and supervisor training; 45 percent is operator training; and 45 percent is professional training for engineers, designers, and technicians.

microelectronics products and for employees who fabricate, assemble, test, and service the products). Other employees receive training in robotics applications, operation, and maintenance; in computer-aided design and computer-aided evaluation of integrated circuits and printed circuit boards; and in a variety of conventional design and manufacturing processes and techniques. Through its educational assistance program, TI covers most of the cost of tuition and educational materials for approximately 4,000 employees who take job-related courses in colleges and universities. Approximately 400 of those employees attend classes on-site at TI plants served by a microwave TV network with hook-ups to such schools as Southern Methodist University, the University of Texas in Arlington, and the University of Dallas.

Texas Instruments' second training and education mission is to find ways to increase the number of adequately educated potential employees. That mission entails working with public and private educational institutions at all levels, and it is that activity which is the focus of this study. Specific programs at various educational levels are discussed in Sections II-IV. Apart from its formal programs and activities, TI management encourages employees to teach in public schools and post-secondary educational institutions. Approximately 200 TI employees in Dallas and other locations teach courses ranging from mathematics for grade school children (see Section IV) to electronics design in community colleges (Section III) to integrated circuit design in universities (Section II). Some examples of TI activities which could not be covered in this study because of space constraints or subject matter focus include a program to hire people with nontechnical degrees as operators in TI's semiconductor manufacturing division; and TI employees who serve as "school champions" for their alma maters and become focal points within the company for recruiting, requests for donations of funds and equipment, and requests for teaching assistance from the particular school from which they graduated. The "school champion" program was created with the intent of aiding the schools by making their liaison within the company a past graduate who has a personal sense of commitment to the school. In that and its other dealings with educational institutions, Texas Instruments acts out of what TI representatives term "enlightened self-interest." TI's corporate manager of training and education explains the philosophy thus:

"We know we can't produce the integrated circuits that form the computers that control the word processors, the numerical control machines, the robots, or the many phases of the space or missile programs unless we have adequately educated people. We will not have adequately educated people unless more students learn math and technology in the schools. We therefore have a broad brush strategy to do our part in educating the potential workforce."

The following pages describe, through a series of examples, how Texas Instruments implements its philosophy of enlightened self-interest at all levels of the educational system.

II. UNIVERSITY LINKAGES

Integrated Circuit Design: Texas A & M University (College Station, TX)

For the past 2 1/2 years, Texas Instruments has been working with the Electrical Engineering Department at Texas A & M* on a program that has expanded the scope and level of knowledge available to students in the department's integrated circuit design courses. Before the TI program began, students in two graduate-level integrated circuit courses produced circuit designs on paper, but because of the prohibitive cost of semiconductor fabricating equipment (\$5-6 million for all of the equipment needed in the process), were unable to fabricate the actual circuits to see how their designs worked out in practice. In response to a proposal made by Texas A & M late in 1979, TI agreed to take the students' designs, verify them using computer-aided "design rule checking" programs; fabricate them on TI equipment; and send the finished product--a silicon wafer containing the student-designed circuits--back to Texas A & M.

* Texas A & M--located in College Station, TX, approximately 180 miles south of Dallas--is a land-grant university founded in 1876. Current undergraduate and graduate enrollment is approximately 35,000. Over 1,200 students (approximately 1,000 undergraduates and 200 graduate students) are enrolled in degree programs in the Electrical Engineering Department.

The program itself began in January 1980 and has now completed its seventh semester. TI's manager of design services, the company coordinator for the program, visits the A & M design class once or twice a semester; stays in telephone contact with the professors; has himself given lectures and has sent other TI experts to give lectures on integrated circuit design; and provides the school with informal advice on such matters as proposed software and hardware purchases.

Initial Activities

During his class visits, the manager of design services critiques the circuit designs generated by the students. In his initial visits in 1980, he observed students working on designs that were, in his words, "aesthetically pleasing, but would result in a malfunctioning circuit." The students, he found, "lacked the awareness that appears to be gained by experience, and the textbooks just did not convey that."

While the TI manager's critique of the students' design was helpful, the most significant aspect of the program was the actual fabrication of the designs by Texas Instruments. According to the manager of design services, "you can point out the obvious design errors, and then it becomes clear that it is a problem that should be taken care of--but the most meaningful way is to do it and to make the mistake and find out the hard way."

The TI fabrication process* stopped short of the actual removal of the circuits from the wafers, the bonding of the gold wire that interconnects the circuit contacts, and the molding of the circuit into its plastic package.

* The fabrication process performed by Texas Instruments begins with inputting the design into a computer. The resulting computer tape is run through a pattern generator (see Case Study #12, GCA products), which produces a master pattern of the design on a photo-resist covered plate called a mask. The master circuit pattern is then reduced in size and exposed on a silicon wafer, which is then developed. According to a TI representative, "After each exposure, the exposed parts of the silicon are etched away, and implanted with various ions in a diffusion furnace and/or metal plated to change the conduction paths generated by the mask exposure. Depending on the complexity of the circuit, the exposure-etch-diffusion process is repeated a number of times." (Ralph Doshier, Texas Instruments, "Vocational Education for the Electronics Communication Industry," paper delivered to the Texas Statewide Conference on High Technology, October 7-8, 1982.)

That bonding and assembly process was left for the students to complete. One of the first student designs sent to TI for fabrication was built on proper theoretical design principles. However, once it was fabricated on a wafer and sent back to the students, it became clear to them that they had neglected to take the requirements imposed by the fabrication and assembly process into account. They did not, for example, take care to place elements that would have to be interconnected in the wire bonding process next to each other. The result was a "spaghetti ball"—an overly complex circuit with wires going helter-skelter which is extremely hard to bond and assemble. According to the TI manager, the students forgot to take into consideration a rule of fabrication and assembly that is so simple it is often overlooked by beginners. As a result of their error, the students got an extremely graphic lesson that showed them some of the pitfalls of circuit-making; and, perhaps more important, they learned to think ahead and to consider fabrication and assembly requirements in the original design stage.

Current Status and Activities

In essence, what the manager of design services did in that first A & M class was to challenge the students to think through the entire circuit-building process rather than to content themselves with "just making pretty pictures from the academic point of view." When the program first got underway, TI verified the students' designs on its computerized design rule checker to make sure that the distances between the circuit elements were correct. This was done before the designs were fabricated to avoid obvious errors. The first designs, according to the TI manager, invariably contained errors that showed up in the verification process. To avoid the "insult" of having their designs rejected even before fabrication, the professors and students at A & M assembled an interactive computer graphics system using existing university-owned hardware and some newly purchased equipment. They also wrote their own software and bought some commercially available software programs for encoding the circuits, simulating their electrical performance, and performing the verification originally done by Texas Instruments. The designs now submitted by A & M students have far fewer errors than the original designs, but there are some errors that do not always appear during the computer-verification

process. One such error which, according to the TI manager, is not properly covered in circuit design textbooks results from calculations that do not take into account what "sheet resistance"--the concept that the resistance between two points is directly proportional to the area between them--can mean in the model parameters of transistors. Often the computer verification will show no resistance, or a constant sheet resistance, but the fabrication process may produce a range of sheet resistance from one side of the wafer to the other. Quite often, students do not take into account this range of sheet resistance, which only shows up in the final product. The actual fabrication process done by TI, then, is essential if the students are to know for certain if their circuits do, indeed, function properly.

Project-Oriented Classes

The Texas Instruments representatives have not influenced the curriculum of the A & M circuit design course--nor do they wish to have an influence over what they believe is the school's prerogative. The program has, however, had an influence on the structure of the course. The course, as it is now, has much more of a project orientation than it did in the past--and this, in itself, provides an additional educational experience to both the professors and the students. Because the students' circuit designs must all be completed by a set date for shipment to Texas Instruments, the professor becomes, in effect, a project manager responsible for seeing to it that all of the designs are ready in time. For their part, the students experience some of the realistic pressures that stem from the necessity of meeting industrial deadlines. This, too, is part of the design discipline; but it is a part of the discipline that is not emphasized on all college campuses.*

* See Case Study #11, "Manufacturing Engineering Applications Center." Worcester Polytechnic Institute in Worcester, MA, has made projects with industry an integral part of its undergraduate engineering programs. There, too, the students learn that the ability to meet project deadlines is a significant part of an engineer's responsibilities.

Results

A direct offshoot of Texas Instruments' participation in the two graduate-level integrated circuit design courses is a new senior-level overview course in integrated circuits. That course was made possible by the hardware and software assembled for simulating and verifying the designs done in the graduate courses. To date, over 150 students have completed one or two of those courses.

Benefits to Texas A & M Faculty and Students. According to A & M faculty representatives, the Texas Instruments program has not only encouraged a number of students who might have moved into other fields to stay in electrical engineering but, in many cases, it motivated them to go on to graduate studies in integrated circuit design and fabrication. In addition, the program has attracted new students to electrical engineering from other engineering and science disciplines. The work on the computer-aided simulation and verification software has brought about cross-fertilization and coordination between students and faculty in the computer sciences and electrical engineering departments.

The students who have gone through the integrated circuit courses have developed an awareness of how to approach a design problem by taking into account the entire design-build process and have developed an awareness of fabrication processes that is often only achieved on the job. TI's manager of design automation has noticed that, during the course of the circuit design class, the students progress from an academic conception of manipulating numbers to a recognition of what those numbers signify in terms of the resulting product. They learn, too, that an aesthetically pleasing design is not necessarily a workable design. They also learn the vital importance of computer-aided testing for errors at every step in the design and fabrication process.*

* See Evaluation, pp. 33-36, for additional results.

Benefits to Texas Instruments. Even though the program involves a good deal of time and expense on TI's part, company representatives believe that the short- and long-term benefits are considerable. The most obvious program benefit is that it produces circuit design engineers who have received a "real-world" education as well as an academic one. TI has hired a number of A & M graduates who have taken the circuit design course (see below for figures), and has further benefitted from the fact that the students hired did not have to be taught "the pitfalls of circuit design" on the job--they had already learned many of these in school. According to TI representatives, the cost of designing a single circuit and fabricating that design on a wafer can be \$1,000,000 or more. One mistake, like a miscalculation of sheet resistance, can cost as much as \$100,000 on top of the \$1,000,000. The student who has made that mistake in school is much less likely to make the same mistake once he or she is in industry and is also likely to be aware of the type and number of small miscalculations that produce \$100,000 errors.

The hiring of A & M program graduates, according to the manager of design services, saves the firm both time and money.* Recently graduated engineers who have not undergone a program like that at A & M will not have the experience of seeing the outcome of their design errors until their first design project has been completed. This could take from 8 to 12 months in ordinary circumstances. The TI manager believes that the A & M graduates enter with this knowledge, and so they are more confident and careful designers from the beginning of their employment. In addition, less supervision by senior engineers is required than for most new engineers. This, too, saves time and money for the firm.

* The manager of design services estimates that well over half of the cost of designing and producing an integrated circuit is salaries for the team of engineers on a circuit design project. When an error occurs that does not show up until the production cycle, the time frame of the project must be extended. A month's extension for a 10-man team of engineers can cost over \$40,000 in salaries alone. In contrast to the actual design/production cycle, the Texas A & M program has negligible labor costs for Texas Instruments. The manager of design services donates his time, and the major costs to the company are in resources required to produce the design (photomask purchase, processing, encoding, and computer time).

Another benefit to Texas Instruments and to the semiconductor industry in general is that the students come out of the program with an appreciation of the value of computer-aided design, testing, and fabrication equipment. They not only know how to use some of it, but they recognize its labor-, time-, and money-saving results and are likely to advocate its use wherever they work. Yet another beneficial result for TI is that the program has attracted more Texas A & M students to electrical engineering--and specifically semiconductor design--and has helped to give the company a positive reputation on the campus to counteract the often-negative student perceptions of industry in general.

Placement of Graduates. Of the 150 students who have completed the circuit verification or design courses, 50 have completed their undergraduate or graduate degree programs. Texas Instruments has hired 12 of those students and, according to the manager of design services, their supervisors are extremely pleased with their performance and are anxious to hire more program graduates. TI representatives believe that, as industry becomes more and more sensitive to the type of skills developed in the A & M courses, customers of Texas Instruments and other semiconductor and computer firms will begin looking for graduates with like skills. According to A & M faculty representatives, graduates who have not been hired by Texas Instruments "have had no end of job offers" from other firms.

Expansion to Other Colleges and Universities. The integrated circuit design program has now been expanded to four other schools: The University of Arkansas, The University of Texas at Austin, Georgia Institute of Technology, and Texas Tech University. Because the computer tapes containing the students' designs and the wafers produced by Texas Instruments can both be shipped, the program is not limited to schools in the vicinity of a TI fabrication plant. Before the schools were accepted into the program, TI's manager of design services visited the campuses to make sure that they had the proper computing equipment to do the design verification and that the faculty members who would be teaching the integrated circuit classes would be given a reduced teaching load (necessary because of the project management responsibilities associated with the program).

Robotics Research

Texas Instruments has recently entered into another joint program with Texas A & M to do research and development in robotics. One goal of the robotics program is to familiarize as many electrical and mechanical engineering and computer science students as possible with robotics technology. Students who have had an opportunity to work with intelligent machines can then use that experience to help them make career choices. The obvious benefit to Texas Instruments is that those students who do decide to focus on robotics applications on the basis of having worked with industrial robots at A & M will require less in-plant training than the average engineering school graduate. TI has donated a T-19102 computer system needed to develop the operating software, and the University has purchased a TI robot (small, extremely precise machines used for electronic assembly*) and has funded a number of faculty members to work on projects aimed at expanding the robots' capabilities. The faculty members will work with a number of student assistants to aid in such projects as developing vision applications and optimizing the mechanical design of the robot arm for greater precision of movement.

Texas Instruments has also donated a computer system to the University of Rhode Island to be used in the development of software based on the PASCAL programming language, which is commonly used in robot programming. TI computing systems have also been donated to Stanford University and to MIT for use in developing robot programming software. In addition, TI plans to donate both computers and robots to Southern Arkansas University which, for the past number of years, has been a source of TI technicians. In all of these instances, Texas Instruments' goal is twofold: 1) to familiarize the students with both the TI computers used to program the robots and with the discipline of robotics, and 2) to enlist the aid of the universities in software and hardware development.

* TI robots are produced for in-plant use only.

III. COMMUNITY COLLEGE LINKAGES

Printed Wire Board Design Program, Eastfield Community College of the Dallas County Community College District (Mesquite, TX)

Unlike the program at Texas A & M, TI's program with Eastfield Community College requires that the company and the school be in close geographical proximity, since the program participants are hired as full-time employees who combine work at Texas Instruments with study at Eastfield for most of the 2-year program. The Eastfield program trains recent high school graduates and TI employees who wish to become printed wire board (PWB) designers.*

Program Initiation

The Eastfield program was initiated by a Texas Instruments representative in the late 1970's. Eastfield College has offered a drafting-and-design degree since the school was founded in 1970. In addition, it is the only college in the Dallas County Community College District (DCCCD) that offers a digital electronics degree.** What Texas Instruments needed, however, was not simply drafting-and-design or digital electronics, but a marriage of the two curricula. TI representatives, therefore, proposed to the college that it create an option within its design and drafting associate degree program called "electronic design," which would include both electronics and drafting/design courses and would prepare students to work at Texas Instruments as printed wire board designers.

* Printed wire boards (PWBs) are often referred to as printed circuit boards (PCBs). The terms are used interchangeably in this report. PWB designers are responsible for designing the layout of the boards containing the integrated circuit chips linked by thin interconnecting wires printed on the surface.

** Eastfield College is one of seven colleges in the Dallas County Community College District. The district itself was created in 1963, and Eastfield was the second of the seven colleges built over a 12-year period. Like the other colleges in the district, Eastfield offers four categories of courses and programs: 1) 2-year associate degree programs in academic subjects, taken in preparation for transfer to 4-year colleges, 2) technical/occupational associate degree programs, 3) credit and non-credit adult education courses, and 4) community service programs on cultural, civic, and other topics. Eastfield is the second-largest college in the district, with 9,000 students enrolled in college credit courses and an additional 3,000 enrolled in non-credit courses per semester.

College representatives looked on the TI proposal with great interest, but took a number of steps to make sure that the need expressed by TI was a general community need before going ahead with the program. Eastfield followed its normal procedure for exploring the feasibility of newly proposed curricular ideas: 1) it created a task force composed of industrial representatives (in this case, electronics industry representatives) plus interested educators and community representatives, and 2) it also initiated a survey to be conducted by the Dallas County Community College District Technical Occupations Program Office to document the need for "electronic designers." Both the survey and the task force (composed of representatives from TI, Rockwell, Western Electric, Mostek, Recognition Systems, and two other firms) substantiated the need for the new category of designers. The industry representatives on the task force aided in curriculum development for the new option and donated some computer-aided design and other equipment required.

While the electronic design option, formally launched in 1978, was open to all interested students, a special program within the option was created for Texas Instruments. The actual coursework taken by TI-sponsored students and others in the electronics option would be the same for required courses; TI students, however, would take specific electives chosen by the company.

Program Responsibilities: Texas Instruments and Eastfield College

The Printed Wire Board Program is, in essence, a program within a program. TI is responsible for selecting both high school graduates and current TI employees whom TI would sponsor as PWB program participants. TI employees desiring to take advantage of the opportunity are given first preference, and recent high school graduates with appropriate math and drafting backgrounds are given second preference. All TI participants, including the recent high school graduates, are on the company payroll from the first day of the program. The program itself consists of one semester of full-time study at Eastfield, followed by three more semesters plus summer courses (taken both before and after work while the participants work 8-hour days in on-the-job training positions at TI). TI provides a program coordinator to monitor and counsel the students on the job and in school. The company also--although

this was not a part of the formal agreement--encourages senior employees to teach some of the electronic design courses at the school. In addition, TI hired two of the Eastfield instructors the summer prior to the program's establishment to work in the Texas Instruments PWB Design Department so they could familiarize themselves with TI's operations.

Eastfield, in turn, provides separate course sections for the TI participants that, in some instances, include information specifically geared to TI work requirements.* Eastfield also assigns administrators and instructors to serve as campus coordinators for the program and to visit the students during the cooperative work experience portions (which take place in all but the first semester). In addition, Eastfield provides weekly progress reports and copies of midterm and final grades to the TI coordinator.

Student Responsibilities, Benefits, and Options

As employees of Texas Instruments, the students are paid for 8 hours per day (40 hours per week) while attending the first semester of classes. Their responsibilities during this section of the program are to maintain a grade-point average of 1.0 ("C"). During the remainder of the program, they are paid only for hours worked at TI (a 40-hour week) and are expected to comply with TI policies, rules, and attendance guidelines while at work. Although they are not paid for class-time after the first semester of full-time study, all of their tuition costs, laboratory fees, and textbook charges are paid in full by the company. The requirement to maintain a 2.0 grade-point average remains in force throughout the program, and students who have "A" or "B" academic averages receive extra wage increases for each semester those averages are maintained (2.2 percent increase for a 3.5 - 4.0 grade-point average and a 1.1 percent increase for 3.0 - 3.49 grade-point average). In addition, all students who continue in the program with passing grades receive regular pay increases at the end of each semester. After completing the first half of the program, the students have the option of dropping the program and

* Because the number of TI participants has not always corresponded to the enrollment requirements for Eastfield classes, open slots in the TI classes have, on occasion, been filled by other students in the electronic design option.

remaining at Texas Instruments in jobs corresponding to their skill classifications at the time. Dropping the program at that point, however, is "highly discouraged because of the possible effect on an employee's career progress."

Program Overview

The PWB program is now in its third year of operation. One group of TI-sponsored students has completed the program, and a new group of 37 students began in September, 1982. Ten students from the current group were already employed at TI; 25 were recent high school graduates; and 2 were Eastfield students.*

Selection. Texas Instruments employees are informed of the program opportunity by fliers posted on "job opportunity boards" throughout the company. High school applicants are recruited through their career counselors, who bring interested students with one year of algebra and one year of drafting to a general recruitment meeting conducted by TI 4 months before a new program cycle is to begin. The meeting, which is both an orientation to the program and an interviewing session, starts off with a 45-minute explanation by TI representatives of the program requirements, participant salaries (\$5.30 an hour at entry for high school graduates), and career opportunities for program completers. At the end of the orientation, all interested students are interviewed individually by TI representatives. Current TI employees who express interest in the program are interviewed separately.

Over 125 applicants were interviewed for the second cycle of the program (13 from TI; 115 high school and college students). On the basis of the initial interviews and formal applications, TI representatives called 50 of the original applicants back for second interviews. While drafting experience or coursework was required and computer experience preferred, the most important qualification for selection for the second round of interviews was math

* The Eastfield students were referred by college instructors.

skills. The 37 participants who were selected after the second interview were those who had the strongest mathematics backgrounds and who displayed both motivation and a professional attitude.*

Coursework/Manual and Computer-Aided Electronic Design. Although computer-aided design (CAD) training is a significant part of the PWB program, students are not introduced to CAD until they have a firm grasp of the basics of electronic design--which includes knowledge of block and logic diagrams, electrical schematics, interconnecting wiring diagrams, printed circuit boards, integrated circuits, component packaging, chassis design, and current electronics industry design practices. During the first cycle of the program, the students did not take computer-aided design until the third semester. This was partially because college and TI representatives believe that instruction in manual PWB design is a prerequisite for learning to use CAD as a design tool, and partially because the school could not obtain computer-aided design equipment until the beginning of the students' second year. The CAD systems used for the first group of students were 10-year-old Applicons (2 terminals) donated by Mostek, a local electronics firm which is a member of the college's Design and Drafting Program Advisory Council and the Electronic Design Option Task Force. While both TI and college representatives believe that the capabilities of the now-outdated Applicons were adequate for instructional purposes, the systems frequently shut down, making it difficult for the TI participants and other students taking the school's computer-aided design course to complete their laboratory work.

For the second cycle of the PWB program, Eastfield has purchased (with an educational discount) a two-terminal Computervision Designer V system with CADDS 4 software. In addition, a Redac Cadet CAD system--a system dedicated to electronic design--was donated to the College by Racal-Redac, Inc. The new equipment has not only made it possible for the school to schedule laboratory sessions with the reasonable certainty that the systems will perform adequately, but it has also enabled Eastfield to expand its CAD offerings.**

* Three women and 8 men completed the first cycle of the program. Of the 37 enrollees in the second cycle, 7 are female and 30 are male.

** Two Eastfield instructors received 1 week apiece of free Computervision (cont.)

The new group of PWB students now takes an "Introduction to Computer-Aided Design" course in the second semester and an advanced course focusing on electrical schematics and printed circuit board design in the third semester.

During the first semester of full-time study, the students cover drafting fundamentals, electronic drafting basics, printed circuit board design, introduction to computer science, and DC circuits. During the second semester (once they have started working at TI and attending school before and after work hours), they take courses in AC circuits, technical math, and introductory CAD. Summer session coursework covers digital computer principles, and the final two semesters cover "Advanced CAD—Electronics" (PCB and integrated circuit design), advanced technical math, descriptive geometry, and two additional PCB courses (during which the students learn to design more and more complex boards, ending with a 4-layered PCB design). The majority of the technical courses consist of 2 hours of lecture and 4 hours of laboratory work a week. The technical mathematics (mathematics focusing on technical applications)* and computer science courses are 3 hours of lecture per week. Students also take two technically-oriented "composition and speech" courses.

Cooperative Work Experience at Texas Instruments. Program participants receive 4 credit-hours per semester for their work at Texas Instruments, which is considered by the college to be cooperative work experience (similar to the co-op programs taken by regular Eastfield students). The Eastfield faculty coordinator works with each student individually to set up a series of five objectives to be met by the student during his or her work experience for the semester. Once the student and the faculty coordinator have agreed on the individual objectives, the coordinator discusses them with the student's

* The first required technical mathematics course begins with a review of arithmetic and then moves to plane and solid geometry, computational techniques and devices, units and dimensions, algebra functions, coordinate systems, simultaneous equations, and stated problems. The second technical math course focuses primarily on trigonometry.

supervisor at Texas Instruments, who is responsible for assigning the student's co-op grade for the semester. The co-op coordinator from the college visits the students at work three times during the semester and discusses any problems that may have arisen with both the student and the supervisor.

TI representatives believe that job rotation during the work experience portion of the program "is the key to accelerated practical knowledge and to meeting TI's agreement with the trainer." Accordingly, the program participants are rotated into various PWB design, manufacturing, and testing areas to give them hands-on experience in all facets of TI's PWB operation. Normally, trainees are rotated each semester, and the set of objectives drawn up by the student and the Eastfield coordinator reflects the activities of the department to which the trainee is assigned.

Texas Instruments also provides company tutors to students in need of extra assistance with their Eastfield classwork. When, for example, a number of students in the advanced PCB course were having difficulties grasping the complexities of multi-layered boards, a design supervisor gave them special demonstrations and tutoring sessions.

Results

Out of 21 enrollees in the first cycle of the program, 12 students completed and are now PWB designers at TI. Five other participants dropped out of the program but are still employed by Texas Instruments in such positions as manual PWB designer, plotter operator (plotters print out final CAD drawings), and machine operator in the manufacturing division. The participant group in the second cycle, now in its second semester, has dropped from 37 to 32--the major reason for the attrition being failure to maintain a "C" average in the classwork.

Problems. Although attrition continues to be a problem, Eastfield representatives report that the 40 percent attrition in the first cycle of the program is not unusual for technical courses in the Dallas Community Colleges, while the 13.5 percent attrition for the first semester of the second cycle is well below the normal drop-out rate (usually 20-30 percent per semester for

technical courses). Both Eastfield and Texas Instruments point to underdeveloped mathematics skills as the major cause of the attrition, in spite of the fact that Eastfield provided math tutoring for those students who required it. TI representatives and many Dallas educational community representatives trace the problem with mathematics to the primary schools. (Section IV of this report discusses the efforts of TI and the Dallas school board to address this problem at its root in the grade schools.) Another obvious cause of attrition is the extremely demanding nature of the program. Students begin at Eastfield by taking a full load of technical courses involving 27 hours a week of laboratory and lecture time. After the first semester, they take three classes a semester during the school year in addition to a 40-hour work week. According to Eastfield representatives, it is the recent high school graduates who find the accumulated work-and-study pressure the hardest to bear. All of the drop-outs in the current program cycle, for example, were recent high school graduates. Eastfield instructors believe that the high school graduates with no formal work experience find it difficult to adjust to the working environment and to carry on their studies at the same time. Enrollees who had past employment experience at TI have less of an adjustment to make, although they, too, must make an adjustment--that of returning to school and relearning how to study.

Eastfield's major problem is one common to the vast majority of schools across the country. That problem is lack of adequate equipment and space to accommodate the TI-sponsored students, the additional 200 students enrolled in the electronics design option, along with the other drafting and design students. Even though the school has built a new computer-aided design laboratory with space for the 8 design terminals it eventually hopes to acquire, the increasing numbers of students who will require computer-aided design courses for both mechanical and electronics design courses will place a continued strain on space and equipment. The 10-year-old Applicons donated by Mostek enabled the school to offer its first computer-aided design course in the Spring of 1981, but the equipment soon became unequal to the demands made upon it. Eastfield has been resourceful in making use of Texas Instruments TI-99 home computers (donated to the school by TI) to provide a basic introduction to computer graphics. However, while very basic electrical

schematics operations can be performed on the TI-99s, they were not built to perform the interactive computer graphics functions necessary for PCB design and can only be used for a basic 2-3 week introduction to computer graphics. The two-terminal Computervision system now installed at the college can, of course, perform any function required in the PWB and regular electronic design course, but student use is limited by the number of terminals available. The Redac Cadet design station is used to perform PWB layout and to instruct students in the use of automated computer programs for placement and routing of electronic components. The two new terminals expected to arrive in the near future will ease the problem, but will not entirely solve it. The space problem is somewhat alleviated by the fact that a number of the advanced courses in the PWB program are delivered at Texas Instruments and are taught by TI employees, who receive part-time instructor salaries from Eastfield for their teaching duties. In general, however, space and equipment remain ongoing problems.

Another problem affecting the students occurred at Texas Instruments. When the first cycle of the program was getting underway, the students and the Eastfield instructors noticed some resistance on the part of supervisors and regular employees in the TI PWB design, fabrication, and test departments. The supervisors' resistance diminished rapidly as those students who remained in the program proved themselves to be good workers and rapid learners. However, once the students "proved themselves" and became sought-after by the supervisors, a rivalry of sorts developed between the program participants and the long-time PWB designers, some of whom were still using manual design methods. This sometimes resulted in reduced assistance to the students by long-time employees who, according to an Eastfield instructor, "realized that the students were destined to pass them by." Such problems, if handled appropriately, can die away in time or can be turned into benefits if they are used to encourage long-time workers to learn the computer-aided techniques employed by the students.

Benefits. In spite of the problems noted above, all three groups--the students, Eastfield College, and Texas Instruments--ultimately receive a number of benefits that outweigh the difficulties. The students who withstood the rigorous 2-year program now have PWB designer jobs which, if they reach the top design category, can bring in salaries of \$9.71 - \$13.49 per hour. Even those who did not complete the program received 1-4 semesters of free education and had the opportunity to explore a new career field. In addition, TI has been able to encourage more women and minorities to apply for PWB design jobs. The orientation and recruitment visits to the high schools give students who would not otherwise know of the existence of the PWB design field an opportunity to learn about the field and to apply for the program.

Eastfield College received a number of immediate benefits. The Electronic Design option initiated by the TI proposal attracts upwards of 200 students per year, many of them sponsored by other local electronics firms. Also Eastfield representatives credit the PWB program with "forcing" the school into acquiring computer-aided design equipment, which a number of design instructors had been promoting without success for the past 8 years. Eastfield now offers three CAD courses (Introduction to Computer-Aided Design, Advanced CAD--Electronics, and Advanced CAD--Mechanical), and it is believed to be the only community college in the Texas area with state-of-the-art CAD equipment. It should be noted, however, that the "benefits received" by Eastfield were not simply gifts but were to a large degree the results of the school's willingness to respond to the initial TI proposal. That involved seeking out county and state funding for the purchase of the Computervision equipment, the work of verifying the community need for the new curriculum option, teacher-training at TI and Computervision, and extra work by the instructors to provide TI with weekly progress reports on the PWB participants.

Texas Instruments perhaps has more to gain in the long run than on a short-term basis. The close to 50 percent attrition in the first cycle of the program certainly cost the company money. Balancing that is the fact that the firm now has 12 PWB designers who are trained in the state of the art, who are familiar with TI design procedures, and who--according to supervisors and Eastfield representatives--are excellent employees. In addition, two other

participants who dropped out of the program mid-stream are now working in PWB-related functions. In the second cycle of the program, the TI coordinator is working more closely with the students and instructors and is encouraging those students having difficulties to take advantage of the individual tutoring services provided by the school.

A definite program benefit that has already been realized is that TI has been able to raise the recruitment standards in the PWB Design Department. The firm now requires PWB applicants to have an associate's degree or work experience equal to an associate's degree. In the long run, however, TI will receive more benefits from the program than the increase in recruitment standards and the 10-20 PWB designers who may graduate every two years into full-scale design positions at the company. Initial calculations done by the TI program sponsors indicated that the firm would recoup its initial investment in the first-cycle students after 3 years (the length of time necessary for the trainees to become completely productive). Now, 3 years after the program was initiated, TI representatives find that they are saving additional money because they no longer have to spend on recruitment for PWB designers.* The creation of the open-entry electronic design option at Eastfield and the school's growing computer-aided design capabilities should produce a growing number of technicians who have many of the skills required by Texas Instruments and who may save the company time and money in entry-level in-plant training.

* Specific program costs were not available. However, TI representatives have provided the following general information on the costs of recruiting PWB designers. Prior to the Eastfield PWB program, the PWB Design Department was forced to do its recruiting out-of-state because of the lack of local applicants educated in PWB techniques. Company representatives made approximately 3 recruiting trips per year at the cost of around \$1,000 apiece. Each trip would usually result in company-paid second-stage recruitment visits to TI for 3 to 4 applicants (at the cost of approximately \$750 per visit). On top of the yearly savings in recruitment (averaging \$10,250-\$11,000), the company also saves on training costs, which include instructors, materials, equipment time, and use of facilities.

IV. PUBLIC SCHOOL LINKAGES: DALLAS INDEPENDENT SCHOOL DISTRICT (GRADES K-12)

Texas Instruments' primary goal in supporting and participating in post-secondary programs is to help the educational institutions provide their students with specific skills and knowledge needed by TI and other electronics firms. However, TI corporate training and education representatives found that, if they waited to get graduates from colleges, universities, junior colleges, and other post-secondary institutions, it was often too late--not necessarily because the post-secondary programs did not produce high quality graduates, but because there were too few students enrolling in engineering and technology programs. In the words of TI's manager of training and education:

One of the big problems is finding people with the necessary math backgrounds coming directly out of high school. In Texas, only 7 percent of the high school graduates have / math at all beyond first year algebra. That means that only 7 percent are available for any technology jobs. We have to hire about 70-75 percent of our technicians and 75-80 percent of our engineers from outside Texas. That's expensive. The reason we started the program at Eastfield was our lack of trained people to do printed wire board design, and we had a problem in that program because the students had limited math background. Limited math background--that's why we and all the high tech firms in Texas and, indeed, in the rest of the country have a hiring problem.

Project SEED (Grades 4-6)

The real root of the problem, according to the training and education manager, is not in the high schools and colleges but in the elementary schools.

"Students who take full math and technology curricula in high schools," he says, "are those who have come out of the primary grades with a favorable image of math and technology."

In January 1982, TI's manager of training and education became aware of Project SEED (Special Elementary Education for the Disadvantaged), a non-profit organization in Berkeley, California. For 20 years, Project SEED had been extremely successful in teaching mathematics to minorities and to educationally and economically disadvantaged students. Project SEED's goal is to upgrade the image of minority and disadvantaged students by teaching them mathematics--a skill which not only carries intellectual prestige but which is also free of cultural and religious connotations. Of particular interest to

TI's training and education manager was the teaching methodology employed by Project SEED teachers--a highly interactive method that holds the students' interest and has the long-term effect of making them feel positive about the subject. (See pp. 25-26, below, for a more detailed description of the teaching methodology.)

Initial Implementation Efforts

TI's manager of training and education became a Project SEED advocate and spent months attempting to convince the Dallas Independent School District (DISD) to implement a Project SEED program in the district's primary schools. Eventually, when Texas Instruments offered to cover the costs of bringing Project SEED staff members to Dallas from California to teach a demonstration class, the school representatives--who had been interested in the concept but did not have the resources to implement a demonstration program in the middle of a budget year (August 1-July 31)--agreed to the project. The school chosen for the demonstration was a primary school in a lower socioeconomic area, and the participating 5th grade students had "marginal" mathematics skills. The week-long demonstration class was taught in May 1982 by a Project SEED teacher. On the 5th day of the class--which was taught for 45 minutes a day to a group of 25 students--local educators and industry representatives attended the session and videotaped the class in action. On the strength of what was achieved in a single week through the Project SEED method, the school board funded a full-scale 2-year program. Project SEED, school district, and local industry representatives are now discussing the possibility of multi-year funding to enable the project to expand to reach all of the 4th-8th grade students in the public school district.

1982-83 School Year Program

The program began in the Fall of 1982 with a handful of classes in two of the district schools. To start the program off, Project SEED staff again came from California to 1) teach the initial classes, 2) hire local residents and train them to become Project SEED teachers, and 3) train part-time volunteer teachers from Texas Instruments, DISD administrative staff, and local universities.

Teacher Training. The initial teacher-training and classroom teaching went on concurrently. Twenty Texas Instruments employees, together with the university and school district employees (all of whom had well-developed math skills and most of whom had some previous teaching or training experience), began their teacher-training by observing 4th and 5th grade classes taught by Project SEED teachers. After each class, they would question the teacher about the techniques employed. After observing and questioning every day for 3-4 weeks, they began teaching short segments of the classes themselves--building up incrementally from 10 minutes a day to 45 minutes. After each class or class-segment, the teacher-in-training was critiqued by Project SEED professionals, and after approximately 2 months, the TI employees and other volunteer teachers were ready to take charge of their own classes.*

Project Goals and Teaching Methodology

The Dallas project's goals are to make the students "feel good about math," to make them aware of their own abilities to learn a subject which is both abstract and concept-oriented, and to encourage precision of thought. Enhanced basic skills come about as a by-product of the major goals. The long-term objective is to encourage them to pursue mathematics and math-based technology programs in high school and beyond.

The teaching method employed is a rapid-fire question-and-answer format--doubly interactive in the sense that students are free to fire questions at the class at any point. There are no formal lectures, and the teachers learn how to respond to "wrong" answers in a non-threatening and constructive manner. For example, a teacher who gets an "incorrect" answer from a student may ask the student what his or her thought processes were, comment on the essential correctness of the thought process (or say that it is "interesting"), but indicate that the answer was not precisely the one he or she was looking for. All of the students in the class express either

* Even after the volunteers are assigned classes of their own, they--like other Project Seed teachers--are evaluated once or twice a week by other project instructors. This procedure helps the observer to pick up new techniques and prevents the teacher who is observed from becoming lax.

agreement or disagreement with all answers given, and the teacher makes sure to call on someone who disagrees with each answer, whether or not it is "correct." Students learn not to be afraid of giving a "wrong" answer, and the teachers themselves learn that what may at first seem to be an incorrect answer often indicates that the student has conceived of the problem in a conceptually sophisticated manner that goes beyond the expected "right" answer.

Classes are normally fast-paced--thus leaving little time for boredom on the students' part--and the students themselves are asking or answering questions approximately 60 percent of the class-time. Since the Project SEED classes do not replace regularly scheduled math classes but are delivered in addition to them, students are neither tested nor graded in the Project SEED classes.*

Results

Progress. By January of 1983, 25 Project SEED classes serving 20-30 students apiece were being conducted in the two Dallas grade schools. The 4th and 5th grade students attending the classes were covering such topics as logarithms, exponential equations, and beginning calculus. Volunteer-teacher training is continuing, and TI's manager of training and education is working with ARCO and other Dallas companies to secure commitments for more volunteer teachers from industry. The enrollment goal for the 1982-3 school year was 50-60 classes serving a total of 1,500 students. By May 1983, the project had exceeded that goal and was serving 2,000 students (grades 4-8) in 15 schools. Both Texas Instruments and school representatives report that there have been few, if any, problems with the students, approximately half of whom are

* Because scheduling is handled differently in various schools within the DISD, a number of ways have been developed to accommodate Project Seed classes. Some of the schools have "self-contained classes" with completely flexible schedules which allow Project Seed classes to be delivered at any time. Other schools have restructured the entire school day to accommodate Project Seed, shaving a few minutes off all other subjects to come up with the 45 minutes required for project classes. Others have given some time from social studies or other disciplines. In all cases, time allotted to mathematics has increased from 45 minutes a day to 1-1/2 hours a day (half of that Project Seed, half "regular" math classes).

minorities from low income families. Because of the constant class interaction, discipline problems are practically non-existent, and the students have been extremely receptive. According to Project SEED staff members in Dallas, their major problem now is how to decide which students must be excluded until an adequate number of regular and volunteer teachers can be recruited to cover the entire 4th-8th grade school population.

Problems. The majority of the problems have to do with the teachers--both the regular teachers in the Dallas schools and the volunteer teachers from industry. When the program began in September 1982, over 100 Texas Instruments employees volunteered to participate as part-time teachers. Although most of the volunteers had math backgrounds and many had taught mathematics on various levels, only 20 percent of the original volunteers were adept at the Project SEED teaching methodology, either because they were not comfortable with the fast pace of the classes or because their math skills were too rusty to enable them to respond to the wide-ranging question-and-answer format. Other TI employees, trained to teach in the lecture mode, had difficulty accommodating themselves to a teaching method that does not allow the teacher to lecture. Some, however, who felt uncomfortable with the Project SEED method in the beginning, became converts to the method after they became used to it.

Other problems with the TI volunteers had less to do with the classroom teaching than with their responsibilities on the job at Texas Instruments. The teaching is done on company time, but the volunteers are also responsible for completing their regular duties in the remaining hours of the work-day.

Some TI supervisors were unwilling to give up 10 hours a week of their employees' time. In other cases, employees who had been given permission to work with Project SEED were not able to maintain their regular workload. While those employees have since dropped out of the program, others have been found who can accommodate both responsibilities; and many of their supervisors have attempted to reduce the volunteer-teachers' workloads whenever possible. At present, 12 TI employees are teaching Project SEED classes while continuing to perform on the job.

When Project SEED began, some of the regular teachers in the DISD schools-- both math teachers and others--felt threatened by the Project SEED methodology or did not believe that it was an acceptable teaching method. On the other hand, a number of other teachers responded favorably to the teaching method and began experimenting with it in a number of disciplines, including English, history, and social studies. School representatives now say that teacher resistance is no longer a problem and that a number of original opponents have become advocates of the method.

Benefits. Although long term benefits will not be seen for a number of years, the children who have participated in the Project SEED program have already received a number of short-term benefits. According to school representatives, the students are proud of their new-found skills and respond especially well to both the full-time Project SEED teachers and the volunteer teachers from industry. Data for a formal evaluation of Project SEED's accomplishments are now being collected and will be analyzed by the end of August 1983. On the basis of informal information received from some of the Project SEED schools, project staff members predict that the formal evaluation results will be extremely favorable. For example, at the beginning of the school year, 25 percent of the students in one 5th grade Project SEED class were listed as likely to be retained at their current grade level rather than passing to the next grade. Now, all but two of the students are receiving passing grades in math, and the two "borderline" students have increased their proficiency from the 2nd grade level to at least the 4th grade level.

The greatest benefit to Texas Instruments will not appear for 10 or 12 years, when the Project SEED children graduate from technical school or college. In the meantime, however, the TI employees who are teaching the classes have learned a number of communication techniques that are useful on the job,* and most derive pleasure and satisfaction from their teaching. Texas Instruments has established its willingness to provide time, money, and expertise to the

* They learn, for example, group relationship strategies such as how to assess an audience and elicit a positive audience response.

educational institutions and the community at large, and should reap intangible but significant benefits in terms of community support.

High Schools (Grades 9-12)

Texas Instruments has been involved in the design and ongoing implementation of a number of technology programs for high school students in the Dallas area. One recently initiated program, which began in the Fall of 1982, added a Science/Engineering school to the seven other "magnet high schools" in the DISD (each of which has a different subject-area focus).^{*} The magnet high schools draw the most interested and most accomplished students (measured by achievement, proficiency, and basic skills tests^{**}) to centrally located schools to participate in a "fast-track" program for 3 hours each school day. Transportation to and from the home high schools is provided by the district.

The Science/Engineering School had an enrollment of 68 9th and 10th grade students in the 1982-3 academic year. All of the school's students take an "enriched science sequence" during their first year of studies, an important component of which is a computer literacy segment covering the history of computers, computer applications, basic programming, and elementary flowcharting. They are also required to take a course segment on engineering communication (which teaches basic engineering problem-solving techniques and includes a project in which they solve a simple engineering problem and write up their results). Graphics (basic mechanical drawing and blueprint-reading) is another required course. All students take electronics and computer science during their second year. By their third year, students focus the majority of their coursework on either computer science or engineering. The use of the computer as a problem-solving tool is not only encouraged, but expected of the students. The ratio of computers to students is better than 1:3 (the school has 28 computers available to its 68 students).

^{*} A Texas Instruments representative chaired the school board advisory committee when the Engineering/Science magnet high school was planned.

^{**} Students take the TAP (Test of Achievement and Proficiency) and the ITBS (Iowa Test of Basic Skills) prior to admission.

Some emphasis on programmable automation is expected to come about as a natural outgrowth of the school's focus on computer science and engineering. Students in the advanced graphics course will soon acquire plotters for student use. At present, the teaching staff at the Science/Engineering school is made up of certified teachers from the regular district high schools. By the 1983-84 school year, the school principal hopes to have hired professional engineers and scientists who have retired from industry to teach such topics as solid state electronics to the junior-level students. In addition, the school hopes to bring in industrial high-tech trainers to teach on a part-time basis.

Texas Instruments and other local industries--including ARCO, Mobil, Dresser Industries, Sun Oil, and Southwestern Bell--provide guest lecturers to speak on such topics as the various types of engineers employed in their specific companies and the type of work the engineers in various classifications perform. In addition, field trips to view CAD and CAM equipment at TI and the other industrial sites are planned for each semester.

Apart from participating in the planning and programming of the magnet high schools, Texas Instruments also works with a large number of high schools in the DISD and other districts to provide curricular advice for science and technology programs. TI's corporate manager of training and education has given guidance to schools in the process of setting up technology programs, including information on industry's current and near-future needs, aid in setting up curricula, and advice on subjects of interest to industry. Most recently, Texas Instruments, together with Rockwell and E-Systems, have produced a videotape for high school students to inform them of high technology career opportunities in the Dallas area and to encourage them to go on to 2-year colleges to develop skills in electronics and other technical disciplines. A representative from TI or one of the other companies goes to local high schools on request, shows the film, and answers questions from the students.

The long-term goal of Dallas area educational and industrial representatives is for Project SEED to feed into the various programs on the middle- and high-school level. According to Texas Instruments' corporate manager of training and education, "joint industry-education programs for post-secondary and high

school students are essential. However, if the high school graduate does not have the necessary math and science skills, it will be very difficult to succeed in technology courses in college. The reason only 7 percent of Texas high school graduates take any math beyond the required first year algebra is because they 'learned' in the fourth grade (that) math was hard and no fun." Project SEED was implemented to change that perception and, as its name implies, to plant seeds of interest and basic skills in the elementary grades that will prepare a larger number of high school students to enter and succeed in programs focusing on specific technologies.

V. EVALUATION OF PRESENT AND FUTURE CAPACITY TO WORK WITH EDUCATIONAL INSTITUTIONS

As the programs and activities described in the preceding sections illustrate, Texas Instruments' capacity to work with educational institutions involves far more than merely setting aside disposable funds to support educational research and programming or the donation of equipment. The driving force appears to be the company's willingness to invest time, effort, people, and money in cooperative endeavors that--while they can and do produce some significant short-term benefits--are aimed at achieving their greatest results over a period of 5 to 10 years. In addition, it should be evident that those programs could not have been initiated or have operated with any degree of success had not the educational institutions themselves been willing to respond in a collaborative fashion to TI's offers of assistance. Project SEED and the programs at Texas A & M and Eastfield all required the educational institutions or systems involved to exhibit their capacity to grow and change: changes in educational delivery, in class hours devoted to specific subjects, and scheduling (Project SEED); changes resulting in a new degree program (Eastfield); and changes in the goals and methods of teaching high-level engineering design courses (Texas A & M). In other words, the capacity for cooperative endeavor illustrated in this study can be traced to the willingness of both the company and the educational institutions to accommodate the other party's goals while not compromising their individual objectives. In all of the instances described, Texas Instruments and the educational institutions have identified an area where their interests lay in common goals which could be pursued to the benefit of both.

Most of the programs and activities described in Sections II-IV of this study were initiated by Texas Instruments. TI's initiatory stance evolves from its philosophy of "enlightened self-interest" which, in turn, derives from the belief that industry can no longer afford to carry the burden of training its employees in the computer-based skills required to design and manufacture its products. According to TI's corporate manager for training and education, the educational system "could not produce the necessary computer literacy to meet the industry needs spawned by the electronics revolution . . . 30 years ago when the computer age began. Industry had to educate its engineers, its manufacturing people, its salesmen, and its customers. Industry does not want this burden again. But we will work with education to meet the need."

TI has adopted a "broad brush strategy" in working with education to meet its need for well-trained employees and future applicants. Programs like those at Texas A & M and Eastfield have produced short term results by providing the company with engineers and technicians trained to use computer-aided design and evaluation tools and to be aware of the manufacturing knowledge required of skilled designers.

Although Texas Instruments has not invested as much money in Project SEED and the high school programs as it has in its various programs with and donations to colleges and universities, many TI employees have invested considerable time and effort. Aside from the personal satisfaction and increased group interaction skills gained by the TI employees who participate in Project SEED and other K-12 programs, the corporation as a whole does not receive an immediate quantitative benefit from its activities on the public school level. Indirectly, however, and over the long run, these pre-college efforts are the ones that can have the most sweeping effects and produce the greatest benefits for Texas Instruments and other high technology industries.

Texas Instruments' "broad brush strategy," then, is essentially a three-tiered approach aimed at two varieties of benefits. The three tiers are the K-12 programs, the community college programs, and the university programs. The varieties of benefits--both to TI and the schools involved--are near- and long-term paybacks. The three tiers have been described in previous portions of this study. The remainder of this section deals with the two varieties of benefits and the programs' potential as models of industry-education cooperation.

Near-Term Benefits

The near-term benefits to Texas Instruments from the cooperative programs profiled have already been described: employees whose training added practical workplace knowledge and skills to formal academic training; money saved that would have been spent on in-plant training (although this, in itself, may not have equalled the money spent); in the Texas A & M program, potential savings in avoiding design errors which could be made by "green" design engineers who may have had to learn, at company expense, by making costly mistakes due to incomplete knowledge of manufacturing processes; the personal satisfaction of the over 200 TI employees who work with educational programs at various levels; and a positive corporate image in the schools and the community at large.

Most of the near-term benefits accrued to the educational institutions and systems that participated in the joint endeavors. Texas A & M, the University of Rhode Island, Stanford, MIT, and other schools have received donations of funds and equipment. Texas A & M engineering faculty also credit the TI circuit design program with providing the stimulus that has helped the electrical engineering department to "blossom." Over the 3-year span of the TI program, A & M representatives have seen increased job offers to graduates who have taken the integrated circuit design courses, increased faculty interest in the program and in semiconductor research, growth in student enrollments, and a greatly increased ability to conduct high level semiconductor research. The Electrical Engineering Department has, for example, recently received a grant to conduct a research program aimed at cutting down the time required to design a prototype integrated circuit. A & M faculty members who have participated in the program now feel that their original approach to teaching circuit design was "naive" and believe that they are in a much better position to make a real contribution to both academic and industrial research now that they have an appreciation of the pitfalls involved in circuit fabrication. Specific credit, they say, goes to the TI manager of design services, whose personal commitment to the program was the key to its success. A & M faculty and students should also be credited--not only for their willingness to respond to what amounted to a decisive change in

their traditional mode of teaching and learning integrated circuit design, but also for their efforts in assembling the hardware and writing the software for their computer-aided circuit verification and evaluation system. Three A & M professors are now writing a new textbook on integrated circuit design which will take current fabrication processes into account and will communicate the nuances of circuit design learned in the TI program.

Eastfield Community College has benefitted from the success of the Electronic Design option, which has drawn 200 students and donations of equipment by Mostek and other firms. The Eastfield instructors who spent the summer before the PWB program working at Texas Instruments received an education in PWB manufacturing processes similar to that received by the A & M design instructors in chip manufacturing processes. They, like the A & M instructors, now pass that knowledge along to their students in both the PWB program and the regular courses of the electronics design option. Says one Eastfield instructor: "The student must know about the manufacturing processes because it's easy to sit in a sterile environment with a pencil and paper, or with a CAD terminal, and design something that no one could manufacture. One of the things they have got to know is how they are manufactured and what are the limitations." Eastfield's new courses in computer-aided electrical and mechanical design can also be partially attributed to the Texas Instruments PWB program. According to Eastfield representatives, had Texas Instruments not felt the need to, as they put it, "grow their own technicians rather than hiring from out of state," Eastfield would not now be in the position of having an electronics design option that serves the community at large and of having the beginnings of a computer-aided design lab.

Texas Instruments is less intimately involved with the Engineering/Science Magnet High School than with the other educational programs highlighted in this study. Nevertheless, TI is one of a number of industrial supporters that provide advice, lecturers, and field-trip opportunities for the school. After two semesters of operation, the principal of the Science/Engineering school notes that the majority of the students are responding positively to the increased challenge of the "high expectation curriculum." Of the 68 students

who began the program in Fall 1982, 56 are returning in the Fall of 1983.* The DISD is now considering consolidating a number of the magnet high schools to provide full-day, fast-track curricula to participating students.

Project SEED has produced a number of near-term benefits for the Dallas Independent School District and for the children who have taken the Project SEED classes. Although the formal evaluation of Project SEED's first year in the Dallas area is just beginning, individual teachers who teach the regular school-day curriculum have noted improved mathematics grades, and some have noted an increase in language and verbal skills—possibly due to the large amount of student-teacher interaction in the Project SEED classes. Furthermore, DISD representatives have noticed a significant increase in student interest in mathematics and of parent interest in the public school programs (see "Long-Term Benefits"). DISD representatives also believe that the volunteer teaching done by industrial representatives is beneficial to the school system—not only because the professionals from industry often turn out to be the best Project SEED teachers, but because of the opportunities for increased communication and cooperation between school and industry representatives.

Long-Term Benefits

While the long term benefits are difficult to predict at this stage, the near-term success of the various school projects indicates that, at the very least, there are a number of areas in which industries and educational institutions can work together to the potential benefit of both. The success of the A & M program seems well established and, according to A & M representatives, should continue as long as someone like the TI manager of design services remains in the company to take a personal interest in the program's continuance. The expansion of the program to other schools is likely to produce a larger crop of graduates whose practical knowledge of the problems of integrated circuit design should make them attractive hiring prospects for Texas Instruments, and the firm anticipates other long-term benefits as well. TI operates a number

* A number of students who dropped out did so because the extra school work prevented them from participating in after-school athletics.

of Regional Technology Centers, where the company's customers are taught how to participate in the design of their own unique circuits, which Texas Instruments will then manufacture as part of a microprocessor-based system ordered from TI by the company. Even though the engineers employed by those customer companies--including automotive firms, aerospace companies, and a large variety of other industrial firms--may not actually manufacture the circuits themselves, they will need to understand the fabrication process, with all its constraints and pitfalls, in order to work productively with the TI engineers who design and build the circuits required for their companies' applications. In other words, even if the students who graduate from the circuit design courses at A & M and the other schools do not work for TI, they can--if they work for one of TI's customers--perform the valuable function of interfacing between their companies and the TI designers. Their understanding of the circuit fabrication process may help their companies to become knowledgeable customers who do not make excessive demands because of lack of experience with circuit manufacture.

In spite of the attrition and other problems experienced in the first three years of the Eastfield program, it is producing a small but steady stream of well-trained technicians. The increased counseling and monitoring may reduce the attrition rate in the second cycle of the program, and the new Computervision lab will make the college's job easier. Even if the PWB program does not continue indefinitely in its present form, the Electronics Design option should still produce long-term benefits for TI and other electronics firms in the area by training technicians with the skills in computer-aided and manual design required by the industry.

Although the long-term benefits of the K-12 programs--and especially of Project SEED--will not appear for quite some time, it is these programs which may have the greatest potential impact. If Project SEED can produce students who are interested enough in mathematics to take more advanced high school courses in the math-based science and technology programs in the magnet high school and other high schools, it may, indeed, increase the number of high school graduates interested in and capable of graduating from the post-secondary technology and engineering programs. As mentioned previously, the five students who were dropped from the second cycle of the Eastfield program

all failed on the basis of inadequate mathematics skills. As noted by Texas Instruments representatives, Project SEED—if it continues to be successful—could help solve one of the underlying problems of high school and post-secondary technical education.

In the long run, school representatives believe that both Project SEED and the magnet high schools may help them to counteract "the middle class flight from the public schools" that began after the school desegregation laws were passed. One Dallas elementary school principal reports that a number of families that had sent their children to private schools have now enrolled them in his school because of the success of the Project SEED classes. The principal of the Science/Engineering Magnet High School has also received a number of requests for admission by families with children enrolled in private schools. Another long term potential benefit anticipated by school officials is the possible elimination of remedial high school math and algebra classes. At present, two-thirds of each year's crop of entering high school freshmen must take remedial math. School representatives are so encouraged by the interim success of Project SEED that they are now anticipating that they may be able to eliminate, or at least reduce, the remedial math classes in the high schools once the project has been operating for 4 or 5 years.

Industry-Education Alliances: Pitfalls and Potential

From the comments of the educational representatives who have taken part in TI programs, it appears that the company has not overstepped the fine line between educational assistance and subtle coercion which some school representatives feel could turn educational institutions into industrial breeding grounds. Although the present study has concentrated on TI programs and activities that focus on technical education, Texas Instruments representatives have also been active in encouraging schools to strengthen their general literacy requirements—especially in the areas of history, literature, and economics—and in donating TI personal computers that can be used for a variety of computer-aided learning experiences. That, again, proceeds from the company's philosophy of enlightened self interest, but it is, nevertheless, of benefit to the educational system.

TI's various cooperative programs and its active participation in educational assistance programs for its own employees and for students in Dallas and elsewhere indicate that the company is willing to act as well as talk. While the educators on all levels who have participated in TI programs know, in the words of one such participant, "where our bread is buttered," they do not feel that they have compromised their general educational goals or independence. Texas A & M representatives note that the TI-sponsored circuit design program has given them the capacity to carry on more high level, "esoteric" research in the area of semiconductor design than they have done in the past. Eastfield's associate dean for technical/occupational programs makes the following statement:

The TI-sponsored FWS program is slightly different than the regular electronic design program. Some colleges would question that and ask, 'are you maintaining your integrity by having a degree program for one particular company?' Somehow, I don't worry about that--when we work with a company that says, 'here's a real need we have,' and they go to the trouble of hiring those people and keeping them and bringing back 37 more, that says to me that our mission to provide the community what it needs is being fulfilled. I would not want to create an entire degree program just for one company--that's why we created the electronic design program with a variety of electives. You don't want your whole program to go down the tubes when there is a layoff. As long as we can be flexible and create a generalized program that meets the philosophical and practical needs of the community and yet change it a bit to specifically meet the needs of one company, we don't feel that our integrity can be called into question.

While it is imperative that educational institutions engage in the kind of self-examination illustrated in the preceding paragraph, it also appears that industry and all levels of academia can discover how and where they can cooperate without requiring concessions that are damaging to the philosophies or goals of either partner. As the various examples of cooperative endeavor in this study demonstrate, the major requirement from industry appears to be--not just money and equipment, although those are important--but time, effort, and commitment on the part of individual managers and other employees. The major requirement from educators appears to be flexibility, willingness to try new methods, and the willingness to admit that industry may have something to teach them. Although the Texas Instruments programs described here are not guaranteed to be successful, it appears that both the educational and

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industrial partners in the TI programs have made every effort to avoid the pitfalls and capitalize on what each has to offer the other.

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Preface

This volume contains papers written for OTA to assist in preparation of the report *Computerized Manufacturing Automation: Employment, Education, and the Workplace*. OTA does not endorse these papers. In several instances, the OTA report reaches somewhat different conclusions because of additional information which was obtained later. These papers, however, may prove valuable for readers needing more detailed or specific information that could be accommodated in the final assessment report, and are being made available for such purposes.

PROGRAMMABLE CONTROLLER TRAINING PROGRAM

INTERNATIONAL BROTHERHOOD OF ELECTRICAL WORKERS, LOCAL 11

LOS ANGELES COUNTY CHAPTER NATIONAL ELECTRICAL CONTRACTORS ASSOCIATION

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SUMMARY

The Los Angeles Electrical Training Trust is the training arm of the Joint Apprenticeship Training Committee of the International Brotherhood of Electrical Workers (IBEW) Inside Construction Local 11 and the Los Angeles Chapter of the National Electrical Contractors' Association (NECA). The Training Trust, supported by Local 11 members and the electrical contractors who employ them, provides a 4-year apprenticeship training program and voluntary courses for Local 11 journeymen. In the late 1970's, the Trust began addressing the need to provide journeyman training in the skills required to install, troubleshoot and maintain the electronic devices that were beginning to replace a number of the hard-wired electrical devices involved in inside-construction in factories, plants, and offices. This study focuses on one set of course offerings provided by the Trust--a series of three courses on the installation, programming, and troubleshooting of programmable controllers.

I. BACKGROUND: Los Angeles Electrical Training Trust

The Los Angeles Electrical Training Trust (ETT) was established in 1964 to support educational and training programs for apprentices and journeymen covered under the collective bargaining agreement between IBEW Local 11 (Inside Construction) and the Los Angeles Chapter of the National Electrical

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Contractors' Association (NECA).^{*} As provided for in the Labor Management Relations Act of 1947, the Trust is jointly operated by local union and management representatives and is supported by regular contributions from Local 11 members and their employers. Under the terms of the current collective bargaining agreement, Local 11 members contribute 5¢ for every hour worked into the Trust, while their employers contribute 15¢ for every employee-hour. While the primary responsibility of the Trust is to provide apprenticeship training, the Los Angeles ETF--along with a number of the other local IBEW training organizations in the U.S.--also operates an active journeyman skills improvement program.

All apprentice and journeyman courses are held in training facilities that are either owned, leased, or rented by the Trust. To accommodate the approximately 7,000 journeymen and 650 apprentices in the Local's Los Angeles County jurisdiction (covering 4,069 square miles) the Trust maintains five training centers: one "Metro Facility" in downtown Los Angeles, and one in each of the district's four other dispatch areas. The Metro Facility, opened in March 1981, contains 7 classrooms, 8,000 square feet of laboratory area (including a \$300,000 process instrumentation lab, as well as laboratories for welding, house wiring, conduit bending, motor controls, transformers, fiber optics, high voltage cable splicing, air conditioning, and fire alarms and

* Local 11 is one of 365 IBEW Inside Construction Locals, whose membership work primarily for independent electrical contractors. The IBEW also maintains Manufacturing Locals, serving electrical/electronic manufacturing firms; Maintenance Locals, whose members do in-plant maintenance; Utility Locals serving public power companies; and Telephone Locals. Because members of Inside Construction Locals often work for a series of small- to medium-sized contracting firms which do not have the resources to provide in-plant skills training, the Inside Construction Locals are among the most active in delivering journeyman training under the auspices of Joint Apprenticeship Training Committees.

The National Electrical Contractors Association maintains 135 local chapters throughout the U.S. The Los Angeles Chapter currently has 230 member contracting firms, 35 of which have 30 or more permanent employees and often provide design and engineering as well as installation services. The remainder of the members employ an average of 10 to 12 full-time workers. NECA members provide electrical contracting services to a wide variety of customers, including manufacturing firms, power plants, newspapers, hospitals, schools, and offices. A number of NECA members are also members of the IBEW.

life safety instruction). Two of the dispatch area training facilities have permanent laboratories, while the other two occupy rented space which is converted into temporary laboratories for training purposes.*

Training Trust Administration and Staff

In accordance with the provisions of the Labor Management Relations Act, the Trust Fund is controlled and administered by a six-member Board of Trustees with equal union-management representation. In addition to the Board of Trustees, the Los Angeles ETT is also served by 5 Joint Apprenticeship Sub-Committees (one in each of the district's five dispatch areas) and the Joint Journeyman Educational Advisory Committee. On the permanent staff of the Training Trust are the director, a staff representative in charge of apprenticeship training, a staff representative for journeyman training, and a senior instructor. The majority of the courses are taught by journeyman electricians who serve as parttime instructors for the Trust.

Board of Trustees

The Trustees--who also serve on the Joint Apprenticeship and Training Committee established under the collective bargaining agreement **--are responsible for the administration of the trust funds, oversight of the training programs, and for ratification of any formal action taken by the Trust. The business manager of IBEW Local 11 serves as a Trustee for his or her tenure of office; and the NECA Chapter Manager serves as an alternate Trustee. The other four members of the board are appointed by the officers of the union and the contractors' association.

* By the en. of 1983, the trust hopes to establish permanent training facilities in all of the dispatch areas.

** A Joint Apprenticeship and Training Committee is established under the collective bargaining agreement between one or more IBEW Inside Construction Locals and the contractors' association in the district (usually a NECA chapter). In most districts, the members of the JATC (usually 3 union and 3 management representatives) are also the Trustees of the training trust fund.

Trust Committees

Because of the large membership of Local 11 and the extensive geographical area in the Local's jurisdiction, a Joint Apprenticeship Sub-Committee (JASC) was established in each of the district's five dispatch areas. Each JASC is composed of 3 union and 3 management representatives, who serve as a governing body for the apprentices and the training in their dispatch area.* The Joint Journeyman Educational Advisory Committee (JJEAC) was established to determine the ongoing focus of the journeyman skills improvement program and to advise the Trust on existing and potential skill markets in the Los Angeles area. The JJEAC also maintains equal union/management representation and is comprised of 5 journeymen (one from each dispatch area) and 5 contractors (each of whom has expertise in a different area of electrical contracting). A major goal of this committee is to explore the market for "high technology skills" and to recommend appropriate courses--on programmable controllers, fiber optics, and process instrumentation,** for example--to the Trustees and staff of the Training Trust.

Staff

The Trust director is appointed by the Trustees and is responsible for the ongoing operation of the training programs. The current director, appointed in 1978, has had previous experience as both an IBEW journeyman and an electrical contractor. Both staff representatives have worked as IBEW journeymen and foremen, and both have had previous experience working with training and educational programs. Approximately 25 parttime instructors teach the apprenticeship programs, all of whom are credentialled as parttime instructors by the State of California. The 58 instructors who teach Journeyman courses are not required to obtain State teaching licenses; approximately half of them, however, are credentialled.

* All actions taken by the JASCs and the JJEAC are subject to review and approval by the Trustees.

** See footnote, p. 7.

Philosophy of Training: General Goals

The major goal of the Electrical Training Trust is to deliver comprehensive apprenticeship training and to provide journeymen with the opportunity to improve or reinforce existing skills and to develop new skills required by the changing electrical/electronics field. According to the ETT's director of journeyman training, the line between electricity and electronics is beginning to dissolve; electricians intent on keeping their skills current, therefore, must develop new skills in electronics and computer-aided equipment. Because of the voluntary nature of journeyman training, the Trust's educational philosophy also stresses motivation and creating an awareness of new skill needs to encourage journeymen to take advantage of the training courses offered.* Individual motivation and self-initiative are especially significant, since approximately 25 percent of the membership is hired for relatively short installation jobs out of the union hiring hall. Of the remainder, approximately 60 percent are permanently employed and 40 percent work for two to three contractors per year.

Another aspect of the Trust's training philosophy is that it is the right of each journeyman who works at least 6 months per year to take any course offered in the skill improvement program if he or she has completed the prerequisite courses. To avoid discouraging voluntary participation in the program, no grades are assigned at the end of the courses, and (for the majority of courses) no selection criteria are applied. The introduction of coursework on computer-based equipment like programmable controllers and process instrumentation devices has, however, created exceptions to the general free-enrollment procedure. Because not all of the students who enrolled in the intermediate programmable controller courses had a solid grasp of the fundamentals taught in the basic course, selection procedures have now been instituted for that course. The process instrumentation program--a lengthy series of courses totalling 795 hours--requires students to pass an evaluation as an admission requirement and to pass examinations before proceeding from one course to the next.

* See pp. 24-25 for a description of the informational and motivational efforts of the Trust.

Training Overview

The L. A. Training Trust delivers required courses for apprentices and "pending examination wiremen" (see p. 7) and voluntary courses for journeymen. Apprentices take a total of 840 hours of work-related classroom instruction at the Trust, extending over a 4-year period (3 hours per night, 2 nights per week).^{*} Related instruction courses include electrical code, mathematics, blueprint reading, first aid, pipe bending, welding, instrumentation, basic transistors, and electronics. Applications for the apprenticeship program are accepted every two years in Los Angeles. During the most recent application period, 1,650 candidates applied for the 100 to 200 apprenticeship openings anticipated over the next two years. New apprentices are admitted to the program on the basis of their rank score from the oral interview.^{**}

"Pending examination" (P.E.) wiremen are experienced electricians who have not gone through the apprenticeship program but who instead become members when their employer signs an agreement with the Local. The P. E. program originated in Los Angeles in 1980 and has now spread throughout California and into some other states as well.^{***} P. E. wiremen receive journeyman wages but are required to take an evaluation examination and to attend a concentrated 2-year, 4-semester course series to reinforce their knowledge through formal

* The L. A. Trust's apprenticeship program is based on the 4-year program offered by the National Joint Apprenticeship and Training Committee in Washington, D.C. While the International sets guidelines for apprenticeship training, Locals have flexibility in setting their own programs. The Inside Construction Local in Detroit, for example, requires 672 hours of related instruction, delivered once every 2 weeks (3 hours per day).

** Of the 1,650 recent applicants, 1,150 passed the qualifying examination, which focuses on mathematics skills. Those who qualified on the basis of the examination were then interviewed and were ranked from 1 to 1,150 on the basis of the interview. As apprenticeship openings occur over the next two years, candidates will be called according to their placement on the list.

*** In many areas of the country, experienced electricians who enter Inside Construction Locals when their shops are organized automatically become full-fledged journeymen. Approximately 400 P. E. wiremen are now taking courses at the L. A. Training Trust.

study and to upgrade their skills. At the end of the program, they take the formal journeyman's examination to achieve full journeyman status.

Both the apprenticeship and the P. E. programs are administered through the Los Angeles County Schools' Regional Occupational Program, which serves as registrar for the two Trust programs discussed above.

Approximately 2,000 journeymen completed voluntary skill improvement courses in 1981-1982. The journeyman courses range from 3-week reviews of recent changes in the national electrical code to 13-week courses in advanced blueprint reading to a 3 1/2-year series of courses on process instrumentation.* The journeyman skill improvement program is focused on reinforcing core trade skills and introducing new skills in demand in the local marketplace. Among those new skills in demand are those required to install, program, and troubleshoot programmable controllers, process instrumentation skills, and testing and splicing of fiber optics cable.

Sections II and III of this study focus primarily on the Trust's training program in programmable controllers. Process instrumentation, while it does involve computer-aided equipment, is outside the confines of the "Manufacturing Automation" study, which examines the use of programmable automation technologies in discrete product fabrication and assembly. The NECA contractors who employ Local 11 members install programmable controllers in manufacturing and assembly plants as well as in a wide variety of other industries and enterprises.

* Process instrumentation is the application of electric, electronic, and/or air controls to regulate pressures for measuring fluids or gases and for indicating and controlling levels, temperatures and flow of liquids or gases. Students in the process instrumentation program are taught how to inspect, calibrate, install, tune, and troubleshoot computer-aided instrumentation and process control systems used in chemical and petrochemical plants, refineries, breweries, food processing, and other industries.

II. PROGRAMMABLE CONTROLLER (PC) COURSES

Planning and Development

The need for coursework in programmable controllers was first brought to the attention of the Training Trust in 1978 by members of the Joint Journeyman Educational Advisory Committee (JJEAC). One of the committee members--a general construction manager for a large contracting firm that designs, engineers, and installs computerized systems for materials handling and process control--played an instrumental role by convincing the committee of the need, by providing advice on prerequisite coursework and equipment, and by recommending potential instructors. Following the advice of its "area expert" the committee recommended that the Trust first develop a motor controls course to aid in preparing interested journeymen to take the more advanced PC courses. Westinghouse's Standard Control Division in El Monte, California, proved to be extremely helpful in the development stage, both by providing equipment at a greatly reduced rate and by recommending one of its applications specialists to be the course instructor. The curriculum for the first programmable controller course was developed by the Westinghouse specialist, reviewed and modified by JJEAC to increase its focus on the specific needs of Local 11 journeymen, and approved by the Board of Trustees late in 1980. The first class was offered in October, 1981, and the course has now become a staple offering of the Trust's journeyman skill improvement program. In the Fall of 1982, the Westinghouse specialist who developed and taught the basic course began teaching an intermediate course, PC II, to graduates of the basic course. PC II, a hands-on course covering similarities and differences of four of the major programmable controllers on the market, will be offered in the Summer of 1983.

Goals and Objectives

The specific goals and objectives of the programmable controller courses support the major objective of the Training Trust's journeyman skill improvement program, which is to provide Local 11 members with the opportunity to develop knowledge and skills in all areas of electricity/electronics applicable to employment opportunities in the Los Angeles area covered by the

Trust agreement. This entails not only meeting current needs, but attempting to forecast future needs so that the Local will be able to provide a trained workforce when opportunities occur. Courses that develop skills in high technology fields such as programmable controllers, process instrumentation, and fiber optics are considered by the Trustees and the JJAAC to be crucial areas of education and training for journeymen who want to keep pace with the skill requirements of the local marketplace. In the words of the Trust's director of journeyman training, "The only thing we have to sell are our skills and knowledge--these must be pertinent."

Since the Trust was established to serve both union members and the contractors who employ them, its goal in offering the programmable controller courses is twofold: to provide appropriate skill training to Local 11 members, and to meet the needs of signatory contractors, more and more of whom are making installations involving programmable controllers. The specific objectives of the series of PC courses offered by the Trust are to train journeymen to install, provide power to, program, and troubleshoot programmable controllers. The goal of PC I is to provide a basic introduction to installation and programming requirements so that a graduate of the course could, under the direction of a skilled foreman, aid in PC installations on the job. The goal of the intermediate course is to provide additional information and practice in programming and to teach troubleshooting techniques to enable members to do installation work with less supervision. With the addition of the PC III course, the PC series will fulfill its overall objective--to familiarize advanced students with installation, programming, and troubleshooting techniques specific to the major PC systems in use in the Los Angeles area in order to provide them with increased work opportunities.

Administrative and Instructional Staff

The Trust "staff representative" who directs the journeyman skill improvement training is an active supporter of "high technology training" for journeymen. The journeyman training department took major responsibility for locating the equipment and the instructor for the original PC course and for ongoing coordination of what is now a series of courses on programmable controllers.

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Until the first few months of 1983, all of the programmable controller courses were taught by a single instructor, a Westinghouse applications specialist employed by the sales and customer support group of the Standard Control Division's Numa Logic Department. His prior technical experience includes work as an IBEW journeyman electrician, then as a draftsman, nuclear power engineer, and a control panel designer. Previous to his employment by the Training Trust as a PC instructor, he had taught a series of courses on programmable controllers to employees of the Los Angeles Department of Water and Power. By the Spring of 1983, four new instructors--Local 11 journeymen who have either taken previously offered PC courses at the Trust or who have on-the-job experience--will begin teaching the basic course. In addition, they have completed customer courses, paid for by the Trust and delivered by Allen Bradley, Modicon, and Westinghouse--all major producer of programmable controllers in the U.S.

Equipment

The "Metro Facility" of the Training Trust contains 4 classrooms and 3 classroom/labs, one of which is available for programmable controller courses. In addition, PC classes are also offered on a rotating basis at training sites in four of the district's dispatch areas. As of this writing, the Trust owns two Westinghouse 700 series Numa Logic Programmable Controllers, which are transported by the instructor from one training facility to another as the occasion demands.* The administrative staff of the Trust is currently in the process of purchasing programmable controllers manufactured by Allen Bradley, Modicon, and Texas Instruments in preparation for the PC III course to be offered in the Summer of 1983.

* Whereas the Metro Facility provides secure storage space for equipment, the other training sites do not. Furthermore, classes have, in the past, been offered concurrently at more than one facility. The compact, transportable equipment therefore gives the Trust the flexibility to offer classes at more than one site.

Costs and Funding

The journeyman skill improvement courses are supported entirely by Training Trust funds. Most cost items for the programmable controller courses were not available (administration, instructor salaries, student materials, or classroom rental). The two major items of equipment currently in use--the Westinghouse programmable controllers, valued at \$25,000 each--were purchased by the Trust for a total of \$10,000. In addition, the Trust has set aside funds for the purchase of the other three PC systems to be used in the advanced course.

Costs to Students

Tuition and instructional materials are free of charge to eligible journeymen and apprentices (see Selection, below). However, to encourage students to complete the courses, a \$10.00 deposit is charged at the beginning of every course and is refunded to those students with satisfactory attendance records.

Selection Procedures and Enrollment Trends

Selection

Journeyman skill improvement courses are open to all members of Local 11 who have worked six or more months out of the preceding year for signatory union contractors.* While apprentices as well as journeymen are eligible to take the basic programmable controller course, apprentices are discouraged from doing so until they have learned the fundamentals of the trade. To date, no apprentices have completed the basic course.

* Since the Training Trust is supported by a small proportion of the fringe benefits attached to the wages of working members of the Local and by contractors who are signatory to the trust agreement, employees covered under the IBEW Local 11 agreement who have worked at least half the work-days of the year previous to enrolling in classes have contributed to the trust fund and are therefore eligible. Occasionally, members who have worked less than the normally required 6 months are allowed to attend classes. These decisions are made on a case-by-case basis.

Until recently, no enrollment control existed for either the basic or intermediate PC courses, aside from the necessity of completing the basic course (PC I) before signing up for PC II.* Since, however, regular attendance is the only formal graduation requirement, some graduates of the basic course have signed up for the intermediate course without the prerequisite skills and knowledge to benefit from the more advanced instruction. In February, 1983, a new policy was established whereby members who enroll in PC I take an entrance examination covering motor control theory. Those who do not pass the exam are encouraged to take the motor controls course offered by the Trust before continuing with the basic PC course. Admission to PC II is now at the discretion of the instructor, who will base his decision on a review of the homework exercises required in PC I.** When the advanced course, PC III, is delivered in the Summer of 1983, only those whose homework in PC II exhibits a thorough understanding of the intermediate course will be accepted. Those who are not accepted into PC II and PC III will be encouraged to retake the preceding course to bring their skills up to the required level.

Enrollment Trends/Attrition

According to the Westinghouse instructor, the PC I and II courses have been very well attended, sometimes drawing as many as 32 enrollees for a single course. The complexity of the coursework, however, and the need of some of the PC I enrollees for background coursework in motor controls and solid state electronics, has resulted in an overall attrition rate of approximately 33

* Students with previous experience working with programmable controllers on the job may also test-in to the intermediate course without having completed PC I.

** Successful completion of homework assignments is not a requirement for graduation, only for entrance to the next course.

percent.* While the preferred class size is 12, classes have ranged in size from 8 to 18 students. (Especially large classes are split in two, which, until the recent addition of the two extra instructors, presented problems for the Westinghouse trainer, who had to teach classes twice a week to accommodate all interested students.) Both enrollment and attrition are less in PC II than in PC I.

The employment situation of the journeyman electricians who enroll in the PC courses varies considerably. Some are permanently employed by signatory contractors;** some work for single contractors for long stretches of time (6 to 12 months) on major installation jobs; others work "out of the hall," i.e., are not permanently or semipermanently employed but are rather hired for relatively short jobs out of the union hiring hall. Because of the current economic situation in Los Angeles, a growing number of the students in PC courses work out of the hall. Two additional factors play a part in this enrollment trend: 1) large electrical contractors who provide design and engineering services as well as installation often provide in-house training for their Local 11 employees who install programmable controllers, and it is these contractors who do most of the PC installation in the county, and 2) a number of smaller contractors who are prepared to do installations involving programmable controllers--and who would be likely to encourage their employees to take the PC courses or to hire course graduates--have been affected by the construction slump.

* In recognition of the potential for attrition, the instructor has instituted the following practice. An entrance test concentrating on motor controls theory is given on the first night, and the first homework assignment requires an understanding of the Boolean algebra concepts presented in the first night's lecture. Those students who do poorly on the entrance examination and cannot complete the homework assignment generally do not return for the second session. Because attrition usually occurs before the second night of class, the instructor does not collect the students' \$10 deposits until the second session.

** Contractors who operate "union houses" and are signatory to the collective bargaining agreement between L. A. NECA and IBEW Local 11.

Curricula: PC I - PC III

PC I and PC II were both designed to be 18-hour courses, delivered in 3-hour segments 1 evening a week for 6 weeks. However, because of the amount of material to be covered in the basic course, recent PC I courses have been extended to 7 weeks. PC III, currently in the development stage, will be from 16 to 24 hours in length and will take place on the weekends to enable students to attend intensive 8-hour-a-day classes.

PC I. Students in this introductory course learn terminology, the basics of the theories behind programmable controllers, how to address the equipment, how it works, and basic installation, programming, and applications. Since the majority of students enter the class with limited experience in solid state controls, the first two sessions are devoted to basic theory--an introduction to logic and to Boolean algebra (Session I), an introduction to solid state controls, and a comparison between solid state and electro-mechanical devices (Session II).

Programmable controllers are not introduced until the third session, when students learn what programmable controllers are, how they compare to electro-mechanical controls, and some basic PC applications.

Installation and basic programming (including an overview of input and output devices and special functions involving timers, counters, and other devices) are covered in Session IV. Sessions V - VII are primarily devoted to discussion and practice of programming for specific applications. In addition, Session VII also covers "multiplexing," i.e., carrying out multiple functions simultaneously in an independent but related manner, an operation that often involves combining several signals so that they can be handled by a single device.

PC II provides graduates of the PC I course with the opportunity to practice the basic programming techniques they learned in PC I and to learn more advanced programming applications. For example, they learn to program the PCs to control a "bad parts detector" on a manufacturing plant conveyor system by writing and inputting programs for counting the total number of parts on the line, counting the number of faulty parts,

and for rejecting the parts that are flawed. In addition, the students complete a number of troubleshooting exercises: the instructor puts "bugs" into the classroom equipment and requires the students to tell him why the equipment is not working, how they would fix it, and what the result will be once the adjustment is made. Both the programming and the troubleshooting experiences are of use to inside wiremen who, when they install programmable controllers, often run a basic program for testing purposes and troubleshoot equipment problems that may occur. Some wiremen may also work for contractors who may be called back to a facility to troubleshoot and repair equipment that they installed initially.

PC III. This course, now under development, will teach graduates of PC II how to install, program, and troubleshoot the major models of programmable controllers currently on the market. Accordingly, the course will focus on teaching the students the differences and similarities between the Westinghouse Numa Logic 700 Series used in PC I and PC II and the models produced by Allen Bradley, Modicon, and Texas Instruments. The Trust is currently proceeding with plans to purchase the equipment, and the Westinghouse instructor is designing the course materials.

Instructional Materials and Teaching Methods

The instructional materials for the PC I course were developed by the Westinghouse instructor specifically for use in Training Trust courses. Using some material from the Westinghouse Numa Logic programming and applications manuals and some original material, he devised an instructional package specifically geared for skilled tradespeople with knowledge of electricity but not necessarily of electronics. The same approach--based on relating the principles, theories, and operation of programmable controllers to the theory and operation of electrical and electro-mechanical devices--is used in lectures and hands-on exercises. When teaching Boolean algebra, for example, the instructor relates it to common electrical problems the trainees already understand, and specific Boolean algebra problems given in class and for

homework are based on actual wiring problems the electricians would be likely to run into in the field. Another example of this approach would be the instructor's method of teaching the theory and operation of timers and counters, which are among the basic components of PC systems. He explains the use and purpose of timers and counters by relating them to relays and electro-mechanical devices; explains how programming takes the place of wiring when dealing with programmable controllers; and assigns in-class, hands-on exercises to reinforce the basic concepts. The initial exercise is always reinforced by a second exercise which is very similar to the first. Homework, including reading and problem exercises, is assigned weekly to further reinforce the material taught in class and to lay the basis for the next week's lecture and laboratory work. Although no final grade is given, tests are given at the beginning and end of the course and are supplemented by weekly quizzes--all of which help the instructor to know what to emphasize for each individual class.

Both PC I and PC II are approximately 70 percent lecture, 30 percent hands-on. In PC II, the programming and troubleshooting exercises become more difficult as the course progresses, as the students are taught to reapply what they have already learned to increasingly difficult problems. No specially designed training manual is used for PC II. Instead, students use Westinghouse programming and applications manuals. Students in PC III will have access to the programming and application documentation for all of the systems taught and will learn to write basic programs and modify existing programs on these systems. In addition, they will learn to identify similar problems in all the models, along with methods for troubleshooting the various systems. Students in this advanced course will be expected to complete a great deal of reading on their own time to free up the majority of the class time for practical installation, programming, and troubleshooting exercises.

To increase the amount of hands-on time available to each student in the PC II classes, a new system was inaugurated in the 1983 Winter-Spring schedule. Each student in these classes had the opportunity to take a programmable controller for a week of at-home practice. In addition, students in future classes will also have access to the new training equipment presently being purchased, which will be made available to them at the Metro Facility when it

is not being used for training purposes.

Course and Student Evaluations

Evaluations of the Courses. Students complete written evaluations of the course, the instructor, the facilities, and the instructional material. While there is no formal course evaluation by the Trustees, the JJEAC, or the Training Trust staff, both the IBEW Local and the local NECA chapter provide unofficial channels for evaluation of the course by both contractors and journeymen. Contractors who employ union members who have completed the class give NECA informal evaluations of the workers' skills, and this information is transmitted to the Trust through the contractor members of the Trustee committee and the JJEAC. Similar informal evaluations reach the Trust via the union representatives who sit on the various committees.

Evaluations of the Students. Since journeyman skill improvement courses are taken on the students' own time and on a voluntary basis, no course grades are given, and it is not necessary to pass a final examination to graduate from any journeyman course. However, the new selection criteria for admission to PC I and PC II will require that students in the less advanced courses illustrate the ability to proceed with more advanced coursework as an admission requirement to PC II and III.

Results

As of February, 1983, 89 Local 11 members had completed the basic course and 29 had completed the intermediate course. Since the Trust has no formal follow-up mechanism for tracking graduates of the journeyman courses, it is difficult to assess the overall results of the training in terms of job performance and/or expanded employment opportunities. Interviews with the Training Trust staff, the PC instructor, students, and contractors have produced some data, which, though limited, illustrate some training results in specific instances.

Of nine journeymen interviewed in the January, 1983, PC II class, one was currently working on a PC installation, one had been hired from the hall to

work on PC installations in the past, and another was preparing to become one of the new PC instructors. All three were taking the course to increase their applications and troubleshooting skills, and one noted that the course was especially helpful in teaching him to recognize troubleshooting problems. The other six had not had the opportunity to work with programmable controllers on the job, but were taking the course for two reasons: 1) to prepare themselves for future opportunities, and 2) because they believed it was incumbent on them to develop the skill to work with the electronic and computer-aided equipment they now see to be replacing electro-mechanical devices in many operations. Those who worked out of the hall stated that the programmable controller courses they had taken would give them a distinct advantage in obtaining work, since they would be able to respond to "specialty calls" (requests for workers with specific skills) for PC installation when these come into the hiring hall.*

Six of the eight contractors interviewed provided in-house PC training for their Local 11 employees.** One, however, said that he "expects" his employees to take the Training Trust PC courses and that 8 of his employees who had taken the course had improved their skills. While one large contractor who provided formal training classes did not see the need for his employees to take the Trust classes, he did support the training for other, smaller contractors. Three others who provided their own training did not have a present need for more employees skilled in PC installation. They could anticipate, however, a future need and thought that the course graduates would be attractive hiring prospects. One employee of another of the contractors had taken the class but, because the contractor had an adequate number of employees who were experienced in PC installations, the course graduate had not yet had the opportunity to do any installations. He would, though, be "first in line" for such work should the need arise. Another contractor, who

* Although no formal refresher courses are provided for those who do not have the opportunity to practice their new skills on the job, Local 11 members may maintain and increase their skills by taking the more advanced courses. PC III is so designed that students can benefit from repeating it one or more times to get additional hands-on practice.

** Ranging from formal training classes to on-the-job training.

had hired two course graduates, noted that the PC and process instrumentation courses provided by the Trust save contractors time and money by enabling them to make installations without first having their employees trained by equipment manufacturers' representatives.

Both the employers' and the students' evaluations of the PC courses will be discussed in more detail in Section III of this study. In terms of direct results of the training, their comments indicate that a relatively small proportion of the graduates (possibly a third) have had an opportunity to make use of their training on the job. Since, however, graduates of the courses delivered as far back as 1981 were not available for interviews, the actual number of graduates currently using their skills may, in fact, be much larger.

For the remainder of the graduates, the primary result of the training has been to increase their employment potential and to offer them the opportunity to work with a higher level of technology which, according to all the journeymen interviewed, is "more interesting and less dirty" than the "wire pulling" and pipe bending they often do on installation jobs. According to the Westinghouse instructor, who is also engaged in sales and service of PCs and other control system components, today's \$370 million PC market represents a tremendous growth over the last 3 years. He predicts that, by 1990, the market will have grown to at least \$500 million and that one result of that growth will be an ever-increasing need for properly trained workers on the part of electrical contractors who install (and often design and engineer) control systems for manufacturing facilities, processing plants, newspapers, and numerous other enterprises. According to the chapter manager of the Los Angeles chapter of NECA, the training provided by the Trust gives small and medium-sized contractors who do not have the resources to train in-house the opportunity to bid on installations incorporating PCs and other sophisticated controls. Not only will the Trust classes train their permanent employees, but they also help to develop a pool of trained workers in the hiring hall who can respond to the PC specialty calls from contractors. This issue--i.e., the future potential of the graduates and the potential opportunities their new skills create for local contractors--will also be evaluated in Section III. The remainder of this section will focus on problems directly affecting the training courses and the solutions to those problems.

Problems/Solutions

Because such a large proportion of the students do not have the opportunity to work with PCs on the job, it became increasingly clear to the instructor that the amount of class time available for hands-on experimentation and practice on the equipment was inadequate.* Two new procedures, both instituted in the first few months of 1983, lessen the effects of this problem. The extension of the PC I course to seven sessions has added 3 additional hours of hands-on time, upping the total class hours available for laboratory work from 6 to 9. While the extra class time is helpful, students in a class of 12 (the average size of Training Trust PC classes) still have less than a few hours each on the equipment. It is the second solution, therefore, which is the most promising: in the PC II classes that began in January, 1983, all of the students took one of the PC consoles home for a week or more. This gave them the opportunity to apply what they learned in PC I and to experiment with some of the programming applications they covered in the PC II. According to the instructor, an "immense" improvement was seen in both the weekly homework and in the final examination once all of the students had ample hands-on opportunities at their disposal. Another new practice, soon to be instituted, will allow for even more hands-on opportunities. The Metro Facility laboratories will soon be made available during the day and on those nights when PC classes are not in session. This will enable advanced students in PC II and students in PC III to practice on the Allen Bradley, Modicon, and Texas Instruments programmable controllers, while PC I and less advanced PC II students can continue to use the Westinghouse systems at their own homes. Since there is usually little or no overlap in the scheduling of PC I and PC

* The one-third laboratory, two-thirds lecture format of the Training Trust PC classes is similar to the structure of the PC classes at the GM Truck and Bus plant in Pontiac, MI (Case Study #2), which is 70 percent lecture, 30 percent hands-on. The Cincinnati Milacron controller classes (Case Study #1) are 50 percent lecture, 50 percent laboratory work. It should be noted, however, that GM's is a 40-hour course and the Cincinnati Milacron courses range from 40 to 80 hours. Therefore, the 18-hour Training Trust courses allow for only 6 hours on hands-on time, in which the equipment must be shared by 8-18 students, whereas GM provides 12 hours of lab time and Cincinnati Milacron provides 20-40 hours.

II courses, this system should provide ample hands-on opportunities for any student willing to avail himself of them.

A second problem, closely related to the first, is the lack of time in an 18-to-21-hour course to cover a great deal of complex material. Here, again, the extra session recently added to PC I will be of help, as will the recent emphasis on encouraging those who do poorly on the entrance examination to first take the motor controls course. The instructor also encourages his beginning students to take the Trust's process instrumentation course, which covers the fundamentals of solid state electronics and provides those students who take it with basic skills and information applicable to the PC courses. The more information about motor controls and solid state electronics entering PC students have, the easier it becomes to move quickly through the introductory material in the first two sessions and to spend more class time on PC programming, installation, and applications.

Another related problem is the widely varying knowledge and skills of the students. The instructor estimates that, in a class of 12, 4 or 5 usually exhibit a ready grasp of the material. Another 2 or 3 demonstrate a less-than-complete understanding, while the remainder are unable to make the transition between the principles governing electricity and those governing electronics and do not grasp the different approach required by programming as opposed to hard wiring. On the other hand, he notes that many students who "don't get it" the first time around show great determination and repeat the basic course one, two, and even more times. Because the courses offered by the Trust are free of charge to the students, motivated students who nevertheless require additional time to absorb the material have the opportunity to learn at their own pace--and, according to the instructor, "once it clicks, the worst hurdle is over and the rest comes with practice and application." On the other hand, the great variety of aptitude and learning speeds within a single class does present a problem for the instructor and holds back the faster learners. The newly instituted enrollment controls should relieve this problem to some extent, especially in PC II and III, but it is doubtful that it can be entirely solved. Similar problems have been noted in classes delivered by reprogrammable equipment vendors and by many teachers of introductory courses in a vast array of disciplines.

A final problem noted by the instructor is also one that is common to other industrial training courses involving reprogrammable equipment. The problem--resistance on the part of many students in the basic course to the new concepts, theories, and techniques that must be learned--manifests in the Training Trust P.C.I. classes as an initial attitude of skepticism held by as many as half of the first-night enrollees. The instructor, therefore, devotes a portion of the first night's lecture to a general discussion of the growth of solid state controls and computer-aided equipment and the present and potential effects of the changing technology on an electrician's job. He then presents his own perception of the trade--that, in the very near future, if not in the immediate present, there will be two kinds of electricians: technicians and those who, as the technology expands, will be stuck with lower and lower level jobs. Technicians, he says, will get better, steadier work, while the others will spend more and more time in the hiring hall. While most of the students respond positively to his appraisal, a few maintain their skepticism and either drop out of the class or continue attending without applying themselves to the course material. In many cases, it is older workers who are either nearing retirement--or who face the prospect of unlearning much of what they have spent years learning--who are the most resistant to the new technology. On the other hand, a number of older students have learned rapidly and well.

III. EVALUATION OF PRESENT AND FUTURE CAPACITY

According to local and national IBEW representatives and local representatives of the National Electrical Contractors Association, the Los Angeles Electrical Training Trust has the financial resources and the solid backing of both management and labor required to maintain its current level of high technology training and to extend that training into other high technology fields as the needs arise. Local IBEW and NECA officials believe that their working relationship is among the best in the country, and this sentiment is echoed by individual contractors, union members, and the Training Trust staff. The relationship between the union and the contractors association is, of course, a crucial factor affecting the administration, direction, and the specific training courses offered by the Trust, since the Trustee committee, the

educational committees, and all of the subcommittees have equal representation by labor and management.

High technology training courses like those in programmable controllers and process instrumentation are clearly advantageous to both the union and the contractors' association. According to the Westinghouse instructor, manufacturers of programmable controllers are already having difficulty keeping up with installation and service support requests. As the PC market expands, manufacturers like Westinghouse will--as Allen Bradley, Texas Instruments, and Modicon have already done--turn more and more to support system houses operated by electrical contractors and distributors to provide design, engineering, installation, and service to the end-user.* This will result in expanded opportunities for electrical contractors and a correspondingly expanded need for electricians trained in PC installation and service. The PC III training is especially beneficial to the small contractor who operates independently of the major manufacturers and who does not have the advantage of distributing the equipment or of customer referral by the manufacturers. Such small-to-medium contractors must be able to handle installation and service of a variety of models in order to bid on a larger number of contracts and to purchase the best and most cost-effective systems for his customers' specific needs. It is, therefore, to their obvious advantage to have permanent employees who are well versed in a number of different systems and to be able to place PC "specialty calls" in the hiring hall when they need extra workers for a large installation.

Local contractors interviewed had installed programmable controllers in a wide variety of enterprises, including food processing plants, refineries, breweries, battery plants, and shipyards. A number of contractors specialize in conveyor systems and had installed PC-automated conveyors in manufacturing and processing plants and in airports. Two of the larger contractors had, in the past, installed PCs in auto assembly plants--including Ford, GM, Toyota

* Whereas Allen Bradley, Modicon, and Texas Instruments use system houses for sales as well as design, installation, and support services to the customer, Westinghouse plans to continue selling its own systems and to recommend certain system houses for engineering and service.

America, and Honda. Now, however, they are feeling the effects of the economic downturn and are forced to look out of the area for large, heavy manufacturing installation jobs.

Although the depressed state of some segments of the local construction market has resulted in fewer contracts and less work for electricians at the present time, both management and union officials are committed to increasing the training effort. The relatively favorable construction market in years past has produced a sizeable trust fund, making it possible for the Trustees to invest in the equipment and courses they believe are necessary to prepare the workers to compete for present and future jobs. Furthermore, some segments of the market show signs of an upswing. There has, for example, been a recent resurgence of the petroleum industry in the area, which has produced work for contractors and electricians skilled in process instrumentation.

Publicity and Recognition: Crucial Factors

Since the journeyman skill improvement program operated by the Training Trust is based on voluntary participation by the union membership, the present and future success of high technology training for journeymen is partially dependent on the willingness of Local 11 members to attend nonrequired courses in their free time. Accordingly, the Training Trust staff puts a great deal of time and effort into publicizing the courses, encouraging members to attend, and finding ways of providing recognition to course graduates. To publicize the training, quarterly newsletters and training schedules are sent to each member. In addition to local and regional apprenticeship news, the newsletter reports on the progress of individual journeyman courses, keeps members informed of the development of new high tech training, and encourages them to take advantage of the courses offered. A constant theme in Training Trust publications is that it is each member's responsibility to himself to upgrade his skills to avoid becoming professional obsolete. Although the editorials are phrased in encouraging terms, the hard message behind all of them is "If you don't take advantage of high technology training opportunities, you will, eventually, be out of work." Each issue of the newsletter also publishes the names of those who completed courses in the preceding semester. In addition, graduates receive certificates of

completion, formal recognition at union meetings, and patches indicating course completion to be worn on their workjackets. The patch is more than a symbolic gesture, since it alerts employers that the wearer possesses specific skills. In addition, letters are sent to the employers of all course graduates, and evidence of course completion is entered into the rolls at the hiring hall, thus making the graduates eligible for specialty calls requiring skills taught in the course they completed.

The Trust's motivational efforts have been extremely effective. From 1977 to 1980, a total of 676 journeymen completed skill improvement courses. In 1981, once the publicity and reward campaign began, 620 journeymen completed courses, and the course-completion figure for 1982 is over 1,300. Training Trust staff members believe that their own publicity efforts have been aided by the emphasis placed on high technology in the public media and also by word-of-mouth publicity within the union.

Student Response

The individual responses of the PC II students interviewed for this study were similar in tone to the editorials in the Trust newsletters. The students expressed a general belief that the IBEW is "a forerunner in training," that they had been well-trained in the apprenticeship program, and that, now that they had become journeymen, it was up to them to upgrade their skills to keep pace with changes in their profession. One felt that employers "have a right to expect" journeyman electricians to be skilled in programmable controller installation and added that, in the near future, those who do not have such skills will "be something less than journeymen." Because the skills they were learning in the programmable controller classes were new to most of the students, they had difficulty comparing the PC classes to others taken at the Trust, most of which had improved existing skills. Those who had past experience with programmable controllers felt that the class helped them to sharpen their skills, especially in the area of troubleshooting; and those who did not have experience believed that the class would open opportunities "down the road."

Contractor Evaluation

Four of the eight contractors interviewed had either hired graduates of the PC courses or had permanent employees who had taken the courses. In one instance, the contractor was not able to evaluate the PC installation skills of his employee because other, more experienced employees had been doing the PC installation work. Two other contractors had positive responses to the Trust PC courses. The most actively enthusiastic of the contractors said that, although the course "went over things (his employees) already knew," it improved their technical skills and made them "more interested, more aware, and happier with their jobs." He gave the instructor especially high marks for making the students aware of the customers' needs. His hiring procedure, he said, is to hire out of the hall when extra workers are required for a large installation and, when possible, to keep those workers who exhibit an interest in electronics and encourage them to take the Trust's PC classes. Another contractor who had hired PC course graduates noted that the general programmable controller skills (as opposed to the system-specific skills taught in PC manufacturer-delivered courses) were especially beneficial in that they gave the workers the flexibility to work with a number of systems. The final contractor interviewed stated that, while the instructor was knowledgeable, the PC I course--containing only 18-21 hours of class time--could be no more than a familiarization course that course graduates needed on-the-job training and supervision after the course was completed. Since none of his employees had taken PC II, he could not comment on the skill level of the intermediate course graduates.

While the other four contractors interviewed did not have permanent or temporary employees who had taken the Training Trust courses, all but one expressed an interest in hiring the graduates when the need arises. The contractor who did not express interest was the manager of a large system house with an active in-house training staff who felt that in-house training best filled his needs. He did, however, note that one of his Local 11 employees had recently begun teaching programmable controller courses at the Trust and did believe the courses were valuable for other contractors with fewer training resources.

Current Training-Related Issues

Higher Wages for Increased Skills?

One of the most significant training-related issues facing the union and the contractors' association is the feeling on the part of a number of contractors and some union members that those journeyman electricians with high technology skills should draw higher wages than those who do not upgrade their skills. Supporters of the double wage structure for journeymen fall into a number of camps. Some support the notion of a "super-journeyman," i.e., a journeyman who is, essentially, a technician with skills in such areas as solid state controls, process instrumentation, nuclear instrumentation, and/or fiber optics and who would draw a higher hourly wage than journeymen with "low technology" skills. The reasoning behind this position is that those electricians who are already journeymen and have, essentially, been "caught short" by the new technology should not be "punished" for not developing new skills, but that those who do upgrade their skills should be given monetary incentives for doing so. Other supporters of the double-wage structure believe that a "sub-journeyman" classification should be created for those without high technology skills. Sub-journeymen would make less money than fully-fledged journeymen with technician-level skills and, again, would have a monetary incentive to develop expertise in electronics.

Other variations of support for a double, or a sliding, wage scale would not change traditional occupational classifications but would, in some manner, provide higher wages for increased skills. This could be achieved by classifying PC installation, process instrumentation, and other work involving high technology skills as "specialist categories." This means that journeymen working on jobs involving those skills would receive a premium wage for the duration of that job. Two such specialist categories already exist: cable splicers, who do hazardous work on high voltage cables; and electricians who are also certified welders. Both receive extra pay when working on jobs requiring these extra skills. Those who would make PC installation and process instrumentation into specialist categories maintain that this would provide an additional incentive for electricians to upgrade their skills without creating sweeping changes in the occupational structure of the union.

Local and national union officials are opposed to the above-mentioned variations of a wage differential. The business manager of Local 11 points out that the creation of a "super-journeyman" category would place a burden on contractors, who are already paying journeymen a regular wage of more than \$23 an hour in Los Angeles. On the other hand, he believes that the creation of a "sub-journeyman" classification would defeat the philosophy of the apprenticeship program and would serve as a disincentive for apprentices, who would have a double hurdle before becoming fully-fledged journeymen. Creating a "specialist category" for PC installation, he believes, is a stop-gap measure that would, while creating a monetary incentive for electricians, also place monetary restraints on contractors. His approach--which is also the approach of training and education representatives at International headquarters--is to focus on upgrading the general skill level of Local 11 journeymen to include skills in programmable controllers and other solid state electronic skills.

While both the local and international union representatives recognize that their approach is more costly in terms of time (i.e., that higher wages for high technology skills would induce more journeymen to take advantage of training opportunities), they also believe that the industry cannot afford another wage increase. According to Local 11 representatives, those

electricians who do not develop the skills required by the advancing technology will be less and less capable of performing the work and will, eventually, "be phased out" because of inability to obtain work.

International IBEW representatives concur in that prediction and emphasize that the value of a broad-based apprenticeship program is that it creates a flexible tradesperson skilled in a wide variety of tasks. Highly paid specialists, they argue, are too limited for the type of work required by the vast majority of contractors.

Reinforcing Fundamental Trade Skills. Another issue that is receiving increased attention as a result of the focus on high technology skills training is the need to reinforce basic electricity and electronics skills--both as a prerequisite for building advanced skills and as a necessity in its own right. The evaluation of A/C and D/C electricity and of basic solid state

electronics skills required for admission to the process instrumentation courses and the evaluation of motor controls skills recently instituted as prerequisite to admission in the programmable controller course are instances of the Trust's renewed focus on core trade skills. Refresher courses in mathematics for electricians have also been offered.

The significance of the need to reinforce both basic and related skills as the groundwork for instruction in programmable controller installation programming and troubleshooting was graphically illustrated by one of the contractors interviewed. Knowledge of installation and programming procedures for specific brands of programmable controllers could, he pointed out, be dangerous if not combined with a corresponding expertise in the process or procedure the PC is programmed to control. If, for example, an "expert" programmer installed and programmed PCs to control an acid flow process without a corresponding "expert" knowledge of the process, an extremely hazardous situation could occur.

Future Capacity

The future capacity of the Los Angeles Electrical Training Trust to provide training and education in programmable automation and other increasingly technical electronic applications is dependent not only on the internal capacity of the Trust to provide courses but also on the continuing strength of the union itself. A 1980 electricians' strike resulted in higher wages, but it also resulted in the loss of 50 to 100 small contractors from the Los Angeles NECA chapter. The strike, which occurred in June, was followed by a depression in the local construction market, which put further strains on the remaining union contractors. At present, the approximately 40 percent of electrical contractors in the Greater Los Angeles Area who still maintain union shops must contend with nonunion contractors who can often underbid them because of the lower wages received by nonunion electricians.

Both the Local and the International recognize the problem that the higher union wage scale poses for the contractors. What the union has to offer, they say, is responsible negotiation; an insistence on apprenticeship training and an emphasis on journeyman training; and a skilled pool of available labor in the hiring hall that obviates the necessity of "permanently" hiring in times

of plenty and firing in lean times. Los Angeles NECA representatives and local contractors interviewed specifically emphasized their belief that the management of Local 11 is both responsible and responsive to the needs of the contractors. Most of the contractors interviewed believe that when and if interest rates decrease and money loosens up, more and more local industries will consider installing programmable automation systems, resulting in a growth of the PC and related controls market. At present, renewed activity in the petroleum industry is creating jobs in process instrumentation installation.

The L. A. Training Trust--which stressed the value of increased training when times were good--is emphasizing it even more in times of difficulty. It is building its capacity to offer more--and more advanced--courses to those who have the individual motivation and who have responded to the constant encouragement to take advantage of the training opportunities that exist. The PC III course should take instruction in programmable controllers well beyond the "familiarization" level of the PC I course. The process instrumentation program will produce "technicians" qualified at four advancing levels: device level, loop level, system level, and instrumentation/process control level. The Trust is also currently preparing instructors to teach fiber optics courses and is exploring the possibility of purchasing a Heathkit robot for a proposed robotics course.

In addition, the Los Angeles Trust has offered to assist IBEW locals in other nearby jurisdictions by opening the Trust laboratories to other Locals by reciprocal agreement and helping them to design high technology courses. Information provided by the Los Angeles ETT and by other local IBEW training organizations funded by JATC trusts is also being used by the International training organization to develop programmable controller courses that, within the next six months, should spread to at least 100 other training sites and is also developing materials to assist local organizations in teaching semiconductor and fiber optics programs.

It is, however, ultimately the responsibility of individual union members to support the Local's and the International's claims of quality training by voluntarily upgrading their skills in high technology fields. The Training Trust itself is now facing the problem of attempting to provide "quality

training" while, at the same time, providing the opportunity for all of the eligible Local 11 members to attend the courses. The evaluation and selection procedures instituted for the process instrumentation and programmable controller's courses go against the grain of the Trust's basic philosophy, but they nevertheless represent problems that are now being addressed.

To maintain credibility, the Inside Construction Locals must continue to provide workers whose skills are appropriate to the contractors' needs. If training organizations like the Los Angeles Training Trust cannot upgrade the skills of significant numbers of journeymen through the provision of voluntary courses, the union may be forced into giving serious consideration to the "sub-journeymen" concept--which, of all the variations of the notion of wage differentials based on high technology skills, seems to be gaining the most adherents.

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